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ACTIVATED CARBON FROM SOME AGRICULTURAL WASTE PRODUCTS [1]

RAMON SAMANIEGO AND ANTONIO I. DE LEON
Of the Department of Agricultural Chemistry

WITH TWO TEXT FIGURES AND FOURTEEN CHARTS

Activated carbon is extensively used in gas masks and in the manufacture of chemical, pharmaceutical, medicinal, and food products. It is important in the refining of sugar as well as in the decolorization and deodorization of vegetable and fish oils, vinegar, and other industrial products. Because of its effective adsorptive properties, activated carbon is used in the recovery of gasoline, benzene, and other volatile solvents as well as for the removal or reduction of industrial stenches.

Most activated carbons of commerce are of vegetable origin. The Philippines is rich in agricultural waste products which might be utilized in the preparation of active carbon, provided studies on the proper methods of preparation are worked out. The production of an efficient adsorbent carbon does not necessarily depend only on the process followed for its activation. The nature of the raw material, the process of carbonization used, the temperature, and the effect of such treatment on the physical structure of the product are important determining factors that need to be studied.

Review of literature

As early as the 15th century, charcoal was used for removing coloring matter from solutions. Some refineries are said to have used charcoal to clarify sugar since 1794. Charcoal from different species of wood was first charred and used for the purpose. Later, it was impregnated with different inorganic substances and carbonized at various temperatures.

Aside from its use for decolorizing solutions, Hunter (1863) showed that charcoal, because of its high adsorptive capacity for gases, could be used as a gas adsorbent. The World War gave impetus to the study of gas adsorption by charcoal in an attempt to find

[1] Experiment Station contribution, No. 1371. Read before the Los Baños Biological Club, February 29, 1940.

a means of defense against gas. Dewar (1904, 1908) showed the method of activating coconut shell charcoal by steam.

Coates (1921) prepared activated carbon from bagasse at 900°C. Mitsubishi (1933) reported that Tamaru and Imai impregnated sawdust and rice hulls with 10-40 per cent sulfuric acid at 100°C., heated them to 300°C., and later activated the resulting carbons with steam at 900°C. Hene (1935) prepared an activated charcoal from cacao bean shells impregnated with KHS.

Very little work on activated carbon has been done in the Philippines. Santos and Clemente (1930) determined the adsorption of acids and alkalies of forty-one different kinds of unactivated charcoals from Philippine woods. They found that charcoals with a high adsorptive capacity for acids had a low adsorptive capacity for bases and vice versa. Villas[2], Rivera[3], and Abes[4], tried to produce decolorizing carbon from rice bran, rice hulls, copra meal, coconut husks, corn cobs, bagasse, pili nut shells, and several species of Philippine woods for the decolorization of sugar solutions. The materials were impregnated with acids, alkalies, and salts and carbonized at temperatures varying from 400° to 680°C. De Leon and Reyes (1935) reported that unactivated charcoals from several waste products carbonized at 400°C. have very little adsorptive capacity for iodine and were unsuitable for decolorization and deodorization. In an unpublished paper the junior author records that charcoals from agricultural waste produced at 500° and 700°C. and activated with $ZnCl_2$ and phosphoric acid removed color satisfactorily.

Various methods of evaluating the adsorptive capacity of activated carbon are in use. Chaney and St. Johns (1923) showed that the iodine adsorption is a reliable method for evaluating decolorizing carbons. Monti (1932) used the adsorption of methylene blue from a 0.1 per cent aqueous solution as the method of evaluation. Zankl (1935) used the percentage of manganese adsorbed from a 0.5 N $KMnO_4$ solution by active carbon as a means of evaluation.

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[2] VILLAS, TRINIDAD B. Preparation, activation, and evaluation of the decolorizing power of vegetable carbon from Philippine woods and waste materials: I. (Thesis presented for graduation from the College of Agriculture with the degree of Bachelor of Science in Sugar Technology. 1932. Unpublished.)

[3] RIVERA, ANDRES L. Preparation, activation, and evaluation of the decolorizing power of vegetable carbon from Philippine woods: II. (Thesis presented for graduation from the College of Agriculture with the degree of Bachelor of Science in Sugar Technology. 1932. Unpublished.)

[4] ABES, GELACIO P. Preparation and activation of vegetable carbons from some Philippine woods and waste materials: III. (Thesis presented for graduation from the College of Agriculture with the degree of Bachelor of Science in Sugar Technology, 1932. Unpublished.)

Clemente and Pascual (1939) determined the relative activity of charcoals by comparing their power with that of Norit to adsorb methylene blue from aqueous solution and Sudan III dissolved in kerosene. Clemente and Galang (1939) studied the adsorption of methylene blue, Congo red, methyl-violet, and iodine by activated chars.

Fries and West (1921) stated that carbons to be used as gas adsorbents must have a high adsorptive capacity; that is, ability to adsorb and retain large amounts of gas per unit weight of adsorbent and adsorptive activity or high rate of adsorption. In addition, other factors must be considered: versatility, mechanical strength, porosity, chemical stability, corrosive action, and availability of raw material. In estimating the value of a carbon as a gas adsorbent, the U. S. Army Chemical Warfare Service has devised a test in which air containing a known concentration of the toxic vapor is passed at a constant rate into a tube of the adsorbent. The capacity of the carbon is expressed by the number of minutes to the break point; i.e., to the point where a detectable trace of vapor appears in the exit air. The weight of gas adsorbed at the break point is then determined directly. The validity of this test is affected by the concentration of the vapor, the rate of flow, and the fineness of the carbon.

Object of the present work

The present work was undertaken to study the conditions and chemical treatments necessary to prepare active carbon from some agricultural waste products and to evaluate the carbons thus prepared for decolorization and gas adsorption.

MATERIALS AND METHOD

The waste products used in this study were rice bran, rice hulls, coconut shells, corn cobs, lumbang nut shells, and pili nut shells. The materials were reduced to small pieces and air dried before they were carbonized in a cast iron retort (fig. 1) ten inches long and four inches in diameter. One end of the retort was provided with a two-inch plug; the other, with a four-inch plug to which was attached a one-inch nipple, four inches long. At the end of the nipple was joined a one-fourth-inch copper tube, which served to connect the retort to a condenser. Heating was done in an electric muffle furnace in which the temperature was controlled by a calibrated Brown portable pyrometer reading in degrees Fahrenheit at intervals of 20°. The materials were destructively distilled until no more distillate flowed from

the condenser. This took from two to three hours. The retort was cooled, and the resulting carbon was discharged into a tared container.

The unactivated carbons were ground fine enough to pass through a 100 mesh sieve. Fifty-gram portions were weighed into 400 ml. beakers. To these were added an excess of saturated solutions of the activating salts or concentrated solutions of the acids and alkali. The mixtures were allowed to stand for twenty-four hours, after which they were filtered through Buchner funnels by suction. The impregnated carbons were then dried in an electric oven at 105°C. and placed in one-inch pipe iron capsules closed at one end and provided with caps at the other. The capsules were heated to

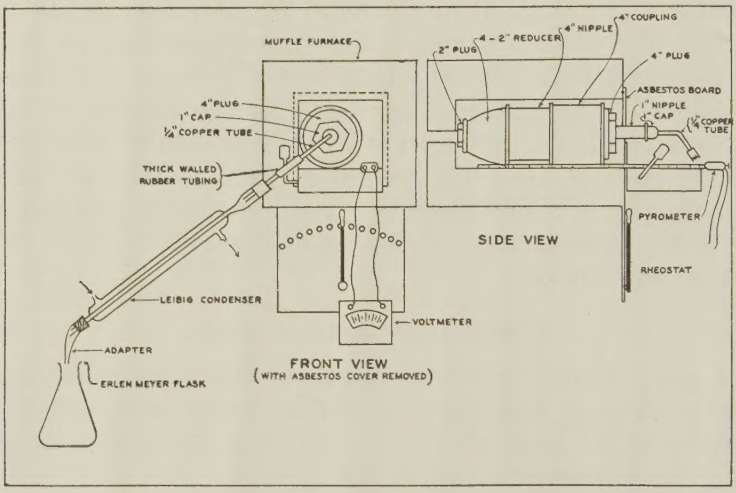

Fig. 1.—Semi-diagrammatic drawing of the set-up for distillation.

960°F. (515.5°C.) for three hours. The activated carbons were cooled, washed with dilute hydrochloric acid and then with water, dried at 105°C., and passed through a 100 mesh sieve. Carbon intended for gas adsorption was ground fine enough to pass through an 8 mesh sieve but coarse enough to be retained by a 14 mesh sieve. In order that the effect of impregnating the raw materials directly could be noted, another series was run in which the raw materials were soaked in saturated solutions of the salts and 10 per cent solutions of the acids and alkali for a week. After this, the solutions were drained off. The raw materials were air dried and then heated to 515.5°C. for three hours. Carbons for decolorization were ground sufficiently fine to pass through a 100 mesh sieve; those for gas adsorption, fine

enough to pass through an 8 mesh sieve, but coarse enough to be retained by a 14 mesh sieve.

The moisture content of the various carbons thus prepared was determined by drying one-gram samples to constant weight in an electric oven at 105°C. The loss in weight represented the moisture in the sample. All determinations were made in triplicate. In order to determine the moisture adsorbing capacity of such carbons, the dried samples were placed in a desiccator containing water and left there until no increase in weights was observed. The increase in weight was the amount of moisture adsorbed by the sample.

For the evaluation of the decolorizing carbons, two grams of activated carbon were weighed into a 250 ml. Erlenmeyer flask and

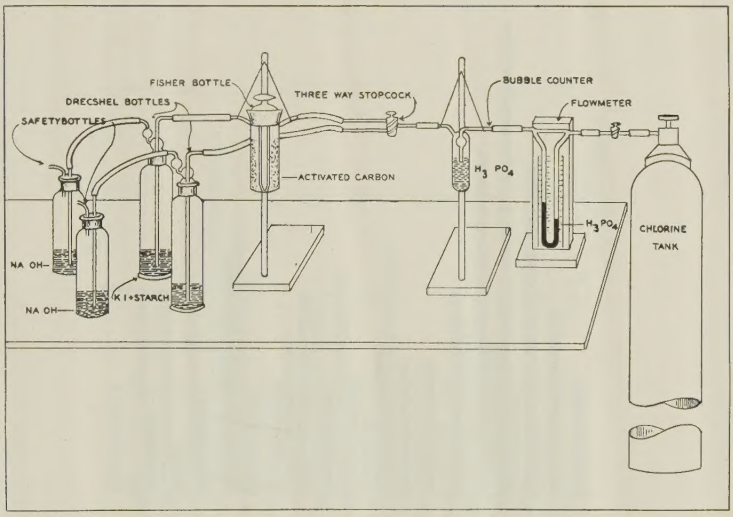

Fig. 2.—Set-up for the determination of chlorine adsorption.

treated with fifty milliliters of 0.1N iodine solution. After ten minutes the solution was filtered through a dry Büchner funnel. The first ten milliliters were discarded. The iodine concentration of a 25-ml. portion of the filtrates was determined by titration.

For the evaluation of gas adsorbent charcoals a gas train was set up. It consisted of (fig. 2) a tank of compressed chlorine, a flowmeter and a bubble counter filled with syrupy phosphoric acid, and a three-way capillary stopcock. One arm of the stopcock was connected to the bubble counter, another to a Fisher adsorption bottle containing the adsorbent carbon, and the third to a Drecshel gas washing bottle containing potassium iodide solution to absorb the incoming gas.

The other end of the Fisher bottle was connected to another Drecshel bottle to absorb the outgoing gas and to a safety bottle filled with saturated sodium hydroxide solution to absorb excess chlorine and prevent its escaping. Another safety bottle of the same type was connected to the Drecshel bottle used to absorb the incoming gas. All connections were made gas tight with paraffin.

The Fisher bottle was filled with the activated carbon to the mouth of the inner tube and then connected with the set up. The

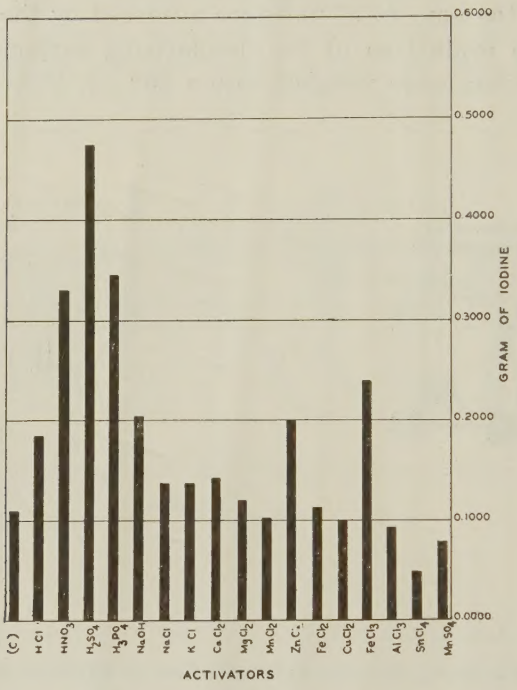

Chart 1.—Gram of iodine adsorbed by activated carbons from rice bran. (Carbonized before impregnating with the activators.)

amount of incoming chlorine gas was first determined by allowing it to flow at a constant rate, as controlled by the flowmeter and bubble counter, into the Drecshel bottle containing a known quantity of 10 per cent solution of potassium iodide for a definite interval of time and then titrating the solution with 0.1N $Na_2S_2O_3$. The gas was then made to pass through the activated carbon in the Fisher bottle by turning the three-way capillary stopcock. The service time was taken with a stopwatch calibrated to 0.2 of a second. By service time is

meant the number of minutes from the time the gas was started through the adsorbent to the time it appears in the exit air, as indicated by a 5 per cent solution of potassium iodide containing starch. The weight of the gas adsorbed was determined by multiplying the weight of incoming gas per minute by the service time. For a basis of comparison, the carbons prepared by the above method were compared with an activated carbon furnished by the U. S. Army Chemical Warfare Service. This carbon was obtained through the cooperation of

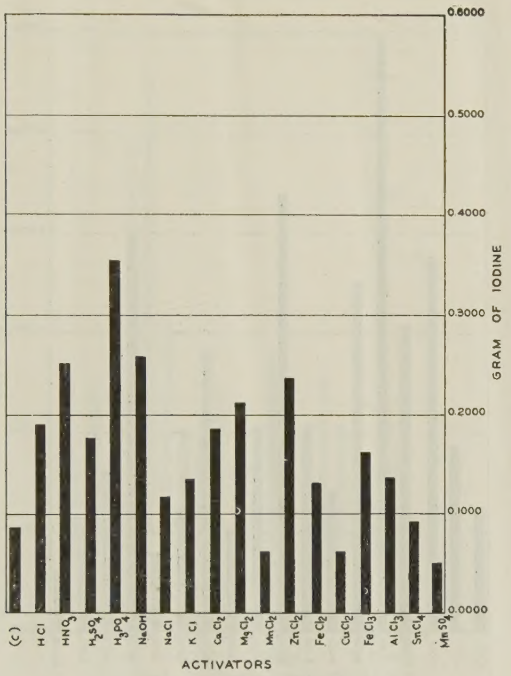

Chart 2.—Gram of iodine adsorbed by activated carbons from rice hull. (Carbonized before impregnating with the activators.)

Col. S. F. Reyes, formerly Superintendent of the R.O.T.C. Units of the Philippine Army.

RESULTS AND DISCUSSIONS

Table 1 shows the average percentages of not less than six replications of the yield of carbon obtained by destructively distilling six different agricultural waste products. The percentages by weight of carbons produced varied from 29.57 to 57.48 per cent. All the materials with the exception of rice bran carbonized at 800°F.

(426.6°C.). Rice bran carbonized at 960°F. (515.5°C.). Comparatively, the yield is in the following decreasing order: rice hull, lumbang nut shell, pilinut shell, coconut shell, corn cob, and rice bran.

Table 2 shows the moisture content, moisture-adsorbing capacity, and the weight of iodine adsorbed by the unactivated carbons. The moisture which varied from 1.19 to 5.61 per cent, that of rice hull and rice bran, respectively, was adsorbed by the carbons during the process of grinding and sieving. Since the length of time of

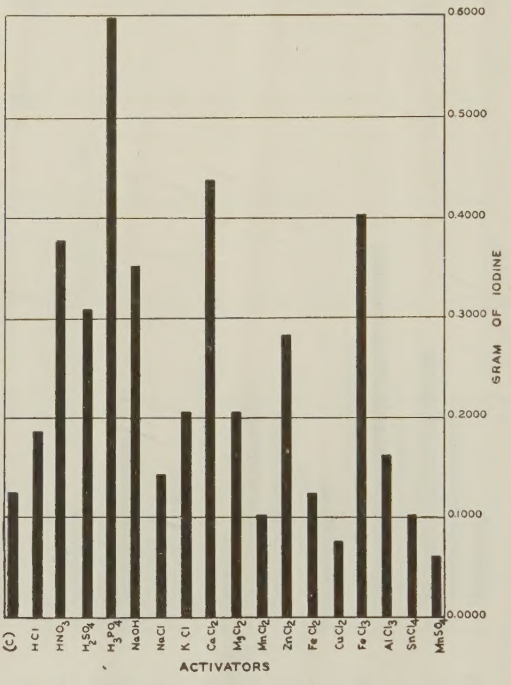

Chart 3.—Gram of iodine adsorbed by activated carbons from corn cob. (Carbonized before impregnating with the activators.)

grinding and sieving was not the same for all the carbons, and the amount of moisture in the air was not the same day by day, these figures are not comparable. The moisture adsorbing capacities were based on the oven-dried carbons and, therefore, are comparable. The correlation between the weight of iodine adsorbed and the moisture-adsorbing capacity was insignificant (coefficient of correlation = +0.085).

Chart 1 shows the iodine adsorption of activated carbons from rice bran. The data show that the best activator for rice bran was H_2SO_4, which increased its adsorptive power for iodine by more than four and one-half times. The carbons impregnated with H_3PO_4 and HNO_3 were about three times better than the unactivated one; with $FeCl_3$, two and one-half times better; and with HCl, NaOH, and $ZnCl_2$, about two times better. NaCl, KCl, and $CaCl_2$ increased the adsorptive power about one and one-half times; $MgCl_2$ and $FeCl_2$ had very little effect. $MnCl_2$, $CuCl_2$, $AlCl_3$, $MnSO_4$, and $SnCl_4$ reduced the ad-

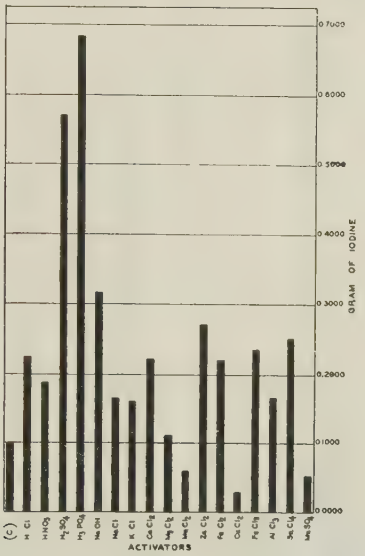

Chart 4.—Gram of iodine adsorbed by activated carbons from coconut shell. (Carbonized before impregnating with activators.)

sorptive power of rice bran for iodine; the last mentioned reduced it by more than one-half.

Chart 2 shows the iodine adsorption by activated carbons from rice hull. These carbons were obtained by destructively distilling rice hull and then soaking it in the activators for twenty-four hours. The best activator for rice hull carbon was H_3PO_4, which increased its adsorptive power a little more than four times. HNO_3 and NaOH gave an increase of about three times; $ZnCl_2$, two and one-half times; HCl, $CuCl_2$, and H_2SO_4, about two times; NaCl, KCl, $FeCl_2$, and $AlCl_3$, approximately one and one-half times. $SnCl_4$ did not materially af-

which increased the adsorptive power about six times; NaOH increased it about three times; $ZnCl_2$ and $SnCl_4$, about two and one-half times; HCl, $CaCl_2$, and $FeCl_2$, approximately two times; and NaCl, KCl, and $AlCl_3$, a little more than one and one half times. $MnCl_2$ and $MnSO_4$ reduced the adsorptive power by one half; $CuCl_2$, by two-thirds.

Chart 5 shows the iodine adsorption by activated carbons prepared from pili nut shell. Pili nut carbon impregnated with H_3PO_4

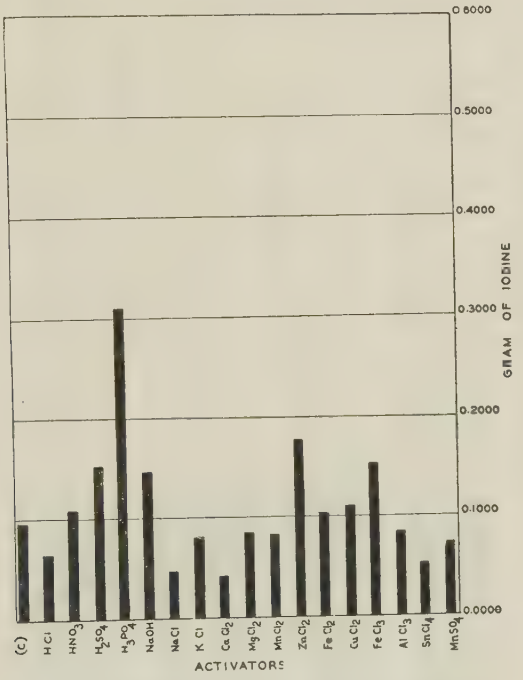

Chart 6.—Gram of iodine adsorbed by activated carbons from lumbang nut shell. (Carbonized before impregnating with the activators.)

had an adsorptive power about seven times that of the unactivated one; with $ZnCl_2$, a little over five times; with NaOH, a little less than two and one-half times; with H_2SO_4, approximately two and one-fourth times; and with HNO_3, about two times. The carbons impregnated with $MgCl_2$, $FeCl_2$, $CuCl_2$, $FeCl_3$ were a little better than the unactivated carbon. HCl, KCl, $CaCl_2$, $MnCl_2$, $AlCl_3$, $SnCl_4$, and $MnSO_4$ decreased the adsorptive power of pili nut carbon.

fect the adsorptive power, whereas $MnCl_2$, $CuCl_2$, and $MnSO_4$ reduced it.

Chart 3 shows the adsorption of iodine by activated carbons from corn cob. The corn cobs were carbonized and activated by soaking in the different salts, acids, and alkali. H_3PO_4 increased the adsorptive power about five times; $CaCl_2$, three and one-half times. Carbons activated with HNO_3 and $FeCl_3$ were three times better than the unactivated one; NaOH, two and three-fourths times; HCl, KCl, and

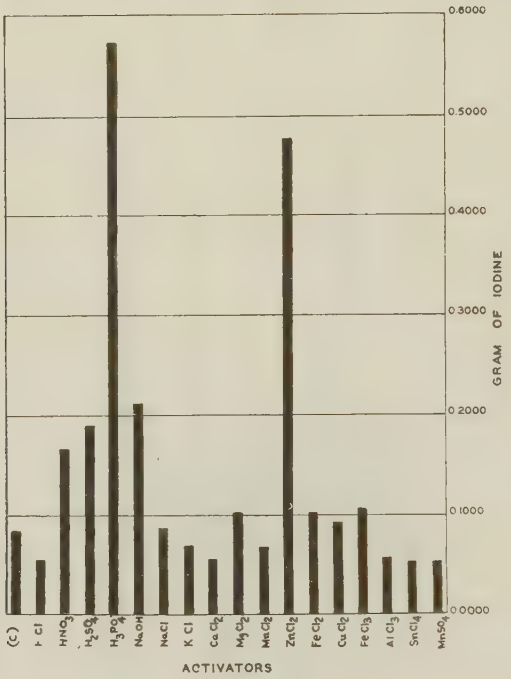

Chart 5.—Gram of iodine adsorbed by ac-activated carbons from pili nut shell. (Carbonized before impregnating with activators.)

$MgCl_2$, about one and one-half times; and NaCl, and $AlCl_3$ about one and one-fifth times. $FeCl_2$ had no effect, whereas $MnCl_2$, $CuCl_2$, $SnCl_4$, and $MnSO_4$ decreased the adsorptive power.

Chart 4 shows the amount of iodine adsorbed by activated coconut shell. These were activated by impregnating the raw carbon with the different chemicals. The best result was obtained with the carbon activated with H_3PO_4, which adsorbed about seven times more iodine than the raw carbon. The next best activator was H_2SO_4,

Chart 6 shows the amount of iodine adsorbed by activated carbon obtained from lumbang nut shell. Treatment with H_3PO_4 gave the best carbon, which was more than three times as effective as the raw carbon. $ZnCl_2$ increased the adsorptive power, a little less than two times; H_2SO_4, NaOH, and $FeCl_3$, approximately one and one-half times. $FeCl_2$ and $CuCl_2$, improved the raw carbon slightly; HCl, NaCl, KCl, $CaCl_2$, $MgCl_2$, $MnCl_2$, $AlCl_3$, $SnCl_4$, and $MnSO_4$ reduced the adsorptive power.

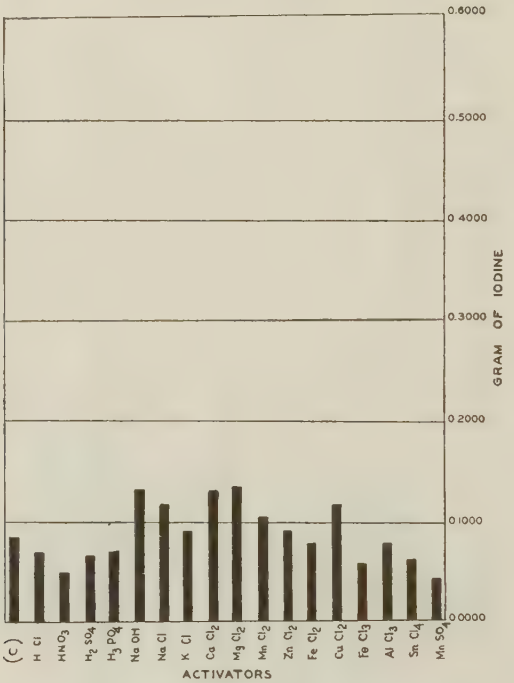

Chart 7.—Gram of iodine adsorbed by activated carbons from pili nut shell. (Impregnated with the activators before carbonizing.)

That the effect of impregnating the raw materials with the activators before carbonization might be observed, pili and lumbang nut shells were soaked in the different impregnating agents for one week, carbonized at 960°F. (515.5°C.), and the adsorptive power of the resulting carbons was determined. The results are plotted in charts 7 and 8.

None of the carbons obtained from pili nuts (chart 7) produced by impregnating before carbonization was improved more than twice.

HNO_3, H_2SO_4, and H_3PO_4 even decreased the adsorptive power of the char. By comparing charts 5 and 7, it will be seen that the adsorptive power of the carbons obtained by carbonizing the raw materials, and impregnating them with HNO_3, H_2SO_4, H_3PO_4, NaOH, and $ZnCl_2$ (chart 5) was more than those prepared by impregnating them with the same activators and afterwards carbonizing them at 960°F. The reverse is true of those treated with NaCl, KCl, $CaCl_2$, $MgCl_2$, $MnCl_2$, and $CuCl_2$.

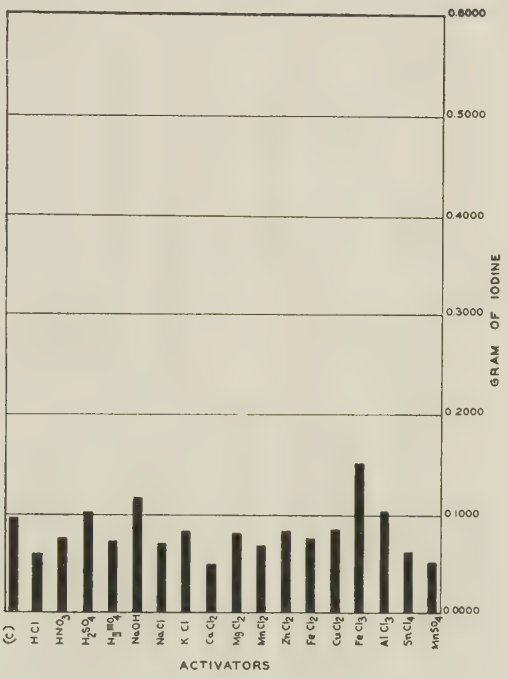

Chart 8.—Gram of iodine adsorbed by activated carbons from lumbang nut shell. (Impregnated with the activators before carbonizing.)

Chart 8 shows that the carbons obtained by treating lumbang nut shells with H_2SO_4, NaOH, $FeCl_3$, and $AlCl_3$ before carbonization were better than the untreated one; however, the improvement was very little.

In the manufacture of gas mask carbon for military purposes, Fries and West (1921) stated that extensive experimental work showed that the most satisfactory materials are nut shells or fruit pits. In addition to their high activity, they have good mechanical strength, which is necessary to avoid packing, crushing, and spreading

dust in containers or towers into which large volumes of gas must be passed at high velocities. For this reason only carbons from coconut shell, pili nut shell, and lumbang nut shell were activated in a manner similar to that used in activating carbons for color adsorption. The adsorptive power of the resulting carbons for chlorine gas was evaluated. The results are presented in charts 9 to 13.

Chart 9 shows the chlorine adsorption by activated carbons prepared from coconut shell. These carbons were obtained by carboniz-

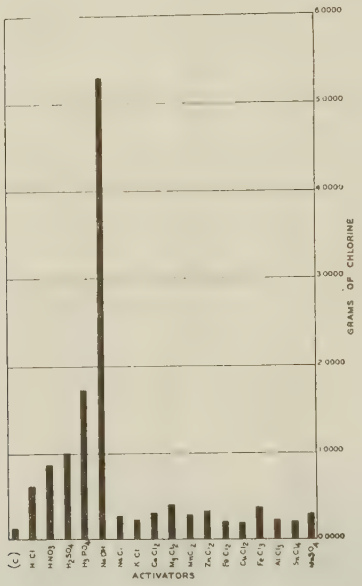

Chart 9.—Grams of chlorine adsorbed by activated carbons from coconut shell. (Carbonized before impregnating with the activators.)

ing coconut shell, then impregnating the carbon with the activators. The untreated carbon has very little adsorption for chlorine gas. The carbon treated with NaOH adsorbed more than thirty-seven times the amount of chlorine adsorbed by the raw carbon. H_3PO_4 increased the adsorptive power of the carbon for chlorine more than twelve times; H_2SO_4, almost seven times; HNO_3, almost six times; and HCl, a little more than four times. All the rest of the activators showed comparatively little improvement. None of the activators, however, reduced the adsorptive power of the carbon.

Chart 10 shows the amount of chlorine adsorbed by activated pili nut shell carbon. Treatment with NaOH improved the carbon a little more than forty-five times; with H_3PO_4, approximately twenty-three times; with HNO_3, about eight and one-half times; and with H_2SO_4, almost seven times. None of the rest of the activators showed marked improvement. Not one of the activators reduced the adsorptive power of the carbon.

Chart 11 shows the amount of chlorine adsorbed by activated lumbang nut shell carbon activated after carbonization. Carbon

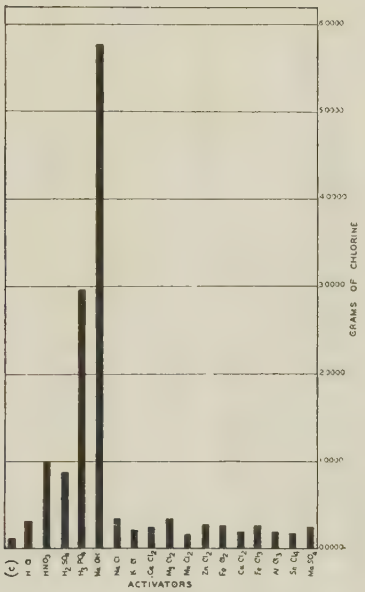

Chart 10.—Grams of chlorine adsorbed by activated carbons from pili nut shell. (Carbonized before impregnating with the activators.)

treated with NaOH adsorbed approximately forty-two times more chlorine than the unactivated. The next best activator was H_3PO_4, which gave an improvement of thirty-two times. H_2SO_4, HNO_3, and HCl gave improvements of seven, seven and one-half, and six times, respectively. The rest of the activators had very little effect on the adsorptive power of the raw carbon; none of them decreased it.

Pili nut shells and lumbang nut shells were soaked in the different activating agents, carbonized at 960°F., and the adsorptive

power for chlorine of the resulting carbons were determined. The results are presented in charts 12 and 13.

Chart 12 shows that although NaOH and H_3PO_4 were the best activators for pili nut shells impregnated before carbonization, very little improvement was observed. None of the activators yielded good carbons. HCl, H_2SO_4, NaCl, KCl, $CaCl_2$, and $MnSO_4$ even decreased the adsorptive power. All the carbons prepared by soaking in the

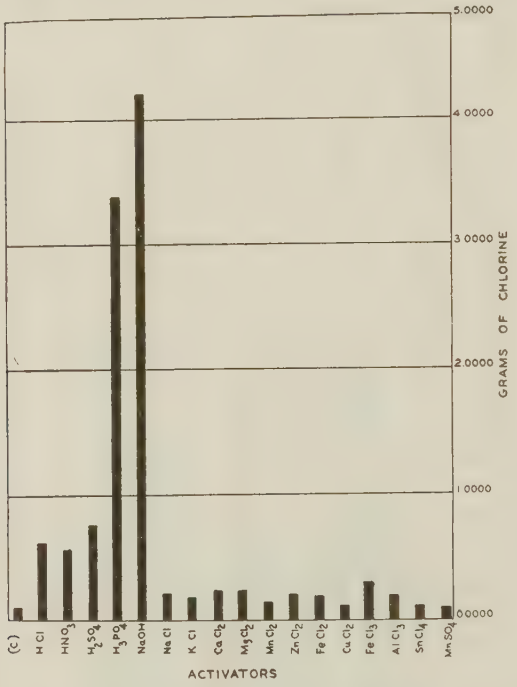

Chart 11.—Grams of chlorine adsorbed by activated carbons from lumbang nut shell. (Carbonized before impregnating with the activators.)

activators before carbonization adsorbed less chlorine than those soaked in the same activators after carbonization.

Charts 12 and 13 compared with charts 10 and 11 show that, as with carbons prepared for decolorization, the method of carbonization followed by impregnation and further carbonization, as a general rule, yielded better carbons for gas adsorption than those produced by impregnating the raw materials first and then carbonizing the impregnated product.

By comparing charts 9 to 12, it may be seen that the best activator for chlorine adsorption was NaOH. The adsorption of chlorine by the carbons activated with NaOH was accompanied by the formation of moisture inside the Fisher bottle and by the evolution of heat. This shows that the adsorption is not only mechanical. According to Kozan (1935), the following reaction may also take place:

$$2\ NaOH + Cl_2 \longrightarrow NaCl + NaClO + H_2O$$

He found that charcoal impregnated with NaOH and $Zn(ONa)_2$ and

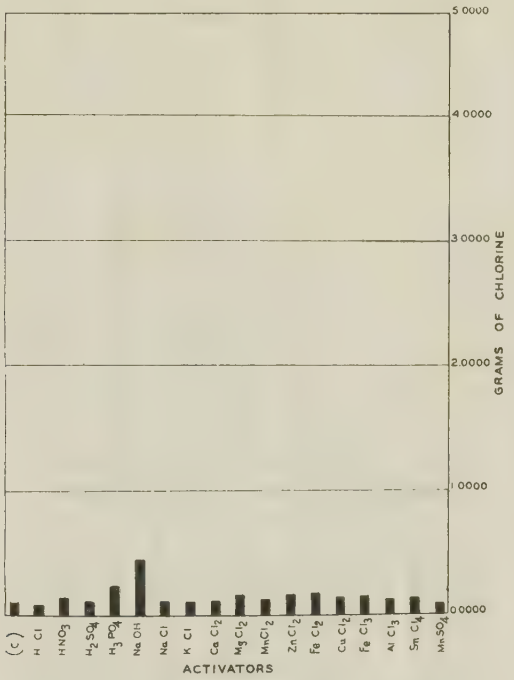

Chart 12.—Grams of chlorine adsorbed by activated carbons from pili nut shell. (Impregnated with the activators before carbonizing.)

heated at 300-800°C. produced active carbon that has a large adsorptive power for acid gases. H_3PO_4, was noted to be the next best activator.

The chlorine adsorption by the best activated carbons from each raw material was compared with that of the Army activated charcoal. The data is shown in chart 14. The best carbon was that obtained by activating pili nut shell with NaOH after carbonization, the second best, from coconut shell, and the third, from lumbang nut shell.

The three above activated carbons adsorbed more chlorine than the Army carbon, whereas those that were activated with H_3PO_4 were not as good.

SUMMARY AND CONCLUSIONS

1. Six kinds of raw carbons and one hundred and thirty-six activated carbons were prepared, and their adsorptive property for iodine was determined.

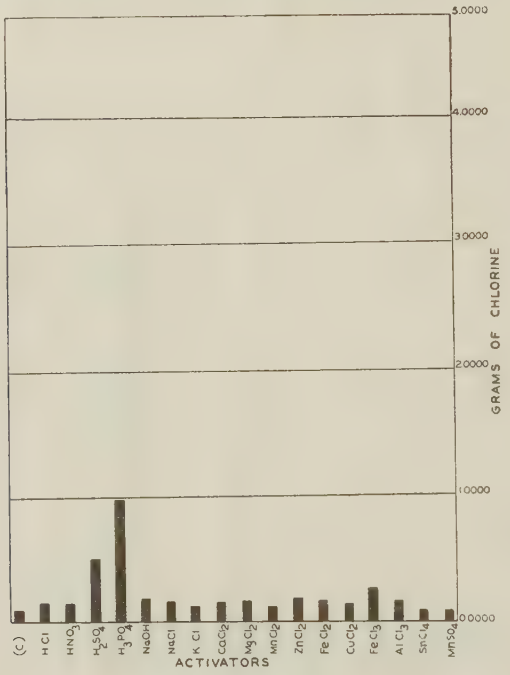

Chart 13.—Grams of chlorine adsorbed by activated carbons from lumbang nut shell. (Impregnated with the activators before carbonizing.)

2. Three kinds of raw carbons and eighty-four activated carbons were prepared, and their adsorptive capacity for chlorine gas was determined.

3. Four acids, one alkali, and twelve salts were used as activators.

4. Two methods of activation were tried: (*a*) carbonization of the raw material followed by impregnation and a further carbonization and (*b*) impregnation of the raw material followed by carbonization. As a general rule, the first method yielded better carbons than the second.

5. The best decolorizing carbon, as indicated by its adsorption of iodine, was that obtained from coconut shell and impregnated with H_3PO_4; the second best, from corn cob and impregnated with H_3PO_4; and the third best, from coconut shell and soaked in H_2SO_4.

6. H_3PO_4, HCl, HNO_3, NaOH, $ZnCl_2$, and $FeCl_3$ were found to be good activators for carbons intended for iodine adsorption.

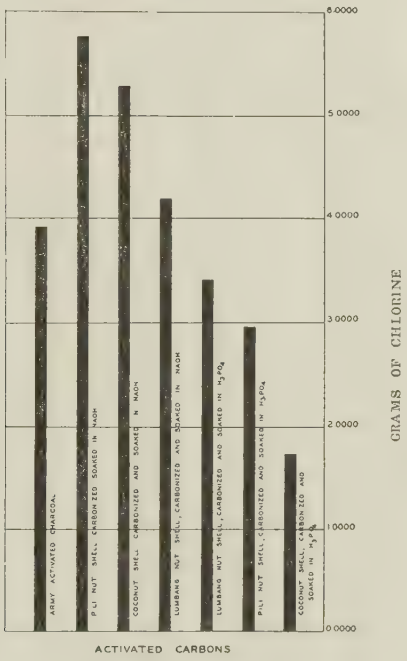

Chart 14.—Grams of chlorine adsorbed by the carbons from each raw material compared with that of the Army activated carbon.

7. The three best carbons for gas adsorption as indicated by the amount of chlorine adsorbed were obtained by impregnating pili nut shell, coconut shell carbon, and lumbang nut shell charcoal with NaOH. Compared under identical experimental conditions, when tried with chlorine gas the above three activated chars gave better results than the U. S. Army activated charcoal.

8. The best activator for carbon intended for gas (chlorine) adsorption was NaOH; the second best, H_3PO_4.

9. $SnCl_4$, $MnSO_4$, and $MnCl_2$ invariably decreased the adsorptive power of the carbons for both iodine and chlorine except the coconut shell carbon treated with $SnCl_4$.

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TABLE 1

Yield of raw carbon obtained from the different raw materials

MATERIALS	TEMPERATURE OF CARBONIZATION	YIELD
	°F.	*per cent*
Rice bran	960	29.57
Rice hulls	800	57.48
Corn cob	800	35.20
Coconut shell	800	36.88
Pili nut shell	800	41.21
Lumbang nut shell	800	54.43

TABLE 2

Moisture content, moisture adsorbing capacity, and weight of iodine adsorbed by the different raw carbons

CARBON	MOISTURE CONTENT	MOISTURE ADSORBING CAPACITY	WEIGHT OF IODINE ADSORBED
	per cent	*per cent*	*gram*
Rice bran	5.61	12.07	0.1116
Rice hull	1.19	5.32	0.0809
Corn cob	3.95	15.12	0.1242
Coconut shell	4.31	8.06	0.1017
Pili nut shell	5.36	9.33	0.0845
Lumbang nut shell	5.01	9.92	0.0946

A STUDY ON COCONUT SEED SELECTION FOR GERMINATION [1]

DIOSCORRO L. UMALI

The germination referred to in this paper means the resumption of growth by the embryo in a seed-nut from the time of planting to the time it becomes visible outside the covering husk. Poor growth or death of the shoot after its emergence from the husk is not considered a failure to germinate.

Blackman (1918) states that the food stored in the seed is mainly responsible for the size and weight of seedling and that the annual growth of a plant, at least in its early stage, follows approximately the Compound Interest Law.

In regard to size and shape of coconuts as indicators of their meat content, Lacson[2] and Novero[3] found that the orbicular, ellipsoid, obovoid, and oblong nuts have less meat than the round ones. These authors further reported that other types than the round nut possess relatively thick husks.

Munro and Brown (1920) state that seed should be taken from trees bearing well at the time of collection or from those showing by records that they have given good average yearly crops for a considerable length of time. Preference should be given to fair-sized, round nuts.

Maceda (1933) found that with equal volume, round nuts germinated earlier than oblong ones. He also found that the seedlings of round nuts were heavier and had more leaves and roots than those of oblong.

Patel (1938) reported that:

a. Progenies of high setting mother trees were distinctly superior in early germination to those of mother trees which yield heavily, produce many female flowers, and have large nuts with thick meat.

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[1] Experiment Station contribution No. 1372. Prepared in the Department of Agronomy under the direction of Assistant Professor Pedro A. David.

[2] LACSON, P. 1921. Size and shape of coconut as indicators of its meat content. (Unpublished).

[3] NOVERO, T. F. 1922. Volume and shape of coconut as indicators of the meat content. (Unpublished).

b. The percentage of germination of nuts from heavy bunches with a minimum of twelve nuts was higher than that of nuts from light bunches with a maximum of six.

c. With the same average ratio of diameter to length, the heavy nuts weighing above one and one half pounds or 0.68 kilogram gave a higher percentage of germination than the light ones weighing below one and one-half pounds.

d. The thin-husked nuts (0.55 to 0.84 inch thick) were superior to any thin-husked (below 0.55 inch thick) and thick-husked (above 0.85 inch thick) ones in both percentage of germination and early germination.

e. Though the progress of germination did not differ much in the nuts from the top, bottom, or middle of the bunch, the percentage of germination was poor in the top and bottom nuts. The dorsal and ventral nuts did not show any difference in germination.

In order to determine the relation of the thickness of the husk, the percentage of setting of the bunches, the size of the bunches, the percentage of female flower-bearing rachillae, the weight of the nuts, and the position of the nuts in the bunch to the germination of the nuts and growth of the seedlings, this study was made in the Department of Agronomy, College of Agriculture, Los Baños, Laguna, from July, 1938, to February, 1939.

MATERIALS AND METHODS

The Laguna type of coconuts borne in 301 bunches from seventeen-year old trees of the College of Agriculture Experiment Station was used in this experiment. These nuts were almost of the same maturity because the Department of Agronomy harvests them regularly every two months.

The nuts were harvested two weeks before planting. Each mature bunch was lowered to the ground with a rope. Those which accidentally fell and those which did not contain water were discarded.

Each bunch was marked heavy or light, and correspondingly numbered. The nuts that developed, the buttons, the female flower-bearing rachillae, and the total rachillae in each bunch were recorded. The percentage of setting for each bunch was determined by dividing the number of nuts that developed by the total number of nuts and buttons in the inflorescence and multiplying by one hundred. The term *buttons* refers to the female flowers that were shed. The percentage of the female flower-bearing rachillae in the inflorescence

was determined, the nuts in each bunch were marked, and the following data were taken:

1. Position in the bunch.
   a. Top—nuts on spikes away from the crown.
   b. Bottom—nuts on the basal spikes in the bunch nearest the crown.
   c. Middle—nuts between the top and bottom nuts in the bunch.
   d. Dorsal—nuts facing away from the tree and exposed to the sun.
   e. Ventral—nuts facing the tree.
2. Percentage of setting and female flower-bearing rachillae.
3. Number of nuts in the bunch.
4. Weight of each nut in kilograms.
5. The thickness of the husks. The thickness was determined by piercing the three protruding sides of the nut with a sharp pointed blade till it touched the shell. The average of the measurements of the three insertions was considered the thickness.
6. The ratio of the diameter to the length to determine whether the nut was oblong or spherical. The diameter is the distance across the nut, and the length is the distance between the two polar ends. When the ratio was above 0.80, the nut was considered spherical and when less than 0.80, oblong.

The nuts for each treatment were selected within the limits of the different ranges given in table 1, for each definite character. In every two treatments the character of the nuts, whose effects were to be compared, had a very marked difference in range, whereas the range of the other characters was practically the same.

Eight beds 8 m. × 1 m. and 1.5 m. apart were prepared. Two treatments in single rows 50 cm. apart were planted in each bed. The nuts were buried to about two-thirds of their volume with the germinating eye up and were distanced 10 cm. in the row. The different lots were given the same care.

EXPERIMENTS AND RESULTS

Fifty nuts were used in each experiment and observed daily at the same hour. The following data were noted:

1. The exact number of days from planting to the emergence of the horny apex of the shoot from the husk.

2. The daily percentage of germination.

After 211 days from the date of planting, the following was determined from each seedling:

1. The average height of the leaves.
2 The number of leaves developed.
3. The weight of the seedlings.
4. The number of roots.
5. The average length of the roots.

These results and observations are given in tables 1 to 7.

DISCUSSION OF RESULTS

Relation of the thickness of husk to germination and growth of seedlings

Table 1 shows that the mean differences of the different characters of the seed nuts used, such as the number of nuts in the bunch, shape (diameter divided by length), weight, percentage of setting of the bunch, and percentage of female flower-bearing rachillae in the inflorescence, were insignificant with the exception of the thickness of husk, which showed a significant difference of 1.6360 ± 0.0657 cm. between the means of the two treatments.

Seed nuts with husks 2.88 cm. thick and less were considered thin-husked and those with 3.98 cm. and more, thick-husked.

The mean difference between the thin- and thick-husked nuts in number of days required for germination and percentage of germination was significant in favor of the thin-husked nuts. The husk of these perhaps offered less resistance to the emerging shoot. None of the shoots were deformed among the thin-husked nuts, whereas six shoots of the thick-husked nuts emerged with difficulty and became distorted.

In general the seedlings of the thin-husked nuts grew better than the thick-husked; the mean differences of the average length and number of roots and number of leaves were statistically significant (table 2). The superior growth of the seedlings of the thin-husked nuts may have been influenced by the greater content of meat. These results are in conformity with those of Maceda (1933), who found that because of the greater amount of meat in the round nuts, the seedlings from them grew better than those from the oblong.

The average height of leaves of the seedlings from the thin- and thick-husked nuts was nearly the same, the difference being insignificant. The lateral growth of the seedlings of thin-husked nuts, as

shown by the diameter of shoot and breadth of leaves, was better than that of the thick-husked nuts.

The weights of the seedlings in the two lots were nearly the same. This was contrary to expectation. Because of the superior growth of the seedlings of the thin-husked nuts, this lot should naturally have weighed much more than the thick-husked. The discrepancy, however, might have been caused by the frequent heavy rains that fell two days before the seedlings were dug up. The thick-husked nuts must have absorbed more water than the thin-husked and consequently weighed more.

Relation of percentage of setting of bunches to germination and growth of seedlings

In this experiment (table 3) all characters studied that might have influenced the nature of the nut were the same except the percentages of setting, in which a very decided mean difference of 26.3600 $\pm$ 0.2107 per cent occurred.

The lowest and the highest setting percentage of the bunches studied was taken to form a basis for classification. Nuts borne on bunches with a percentage of setting of 18.50 and below were considered low; and those with 35.50 and above, high.

The mean difference between the low and high percentages of setting in earliness and percentage of germination, average height and number of leaves, and number and average length of roots of the seedlings was statistically significant in favor of the high percentage of setting in the bunch. The difference, however, in the weight of the seedlings in the two lots was not significant. Although the other characters showed significant increases in favor of the seedlings of nuts of the high percentage of setting, the average weights of the seedlings of nuts of the high and low percentages of setting did not show any significant difference. Examination of the nuts which germinated in both lots showed that the meat, a factor responsible for the weight of the seedlings, was almost used up in all the nuts from the bunches of high setting percentage. On the other hand only a small amount of the meat of nuts from the bunches of low setting percentage was consumed. Sampson (1923) reported that the length of time the seedling will absorb the endosperm (meat) depends upon its rate of development. Consequently the greater development of the roots and shoots of the nuts from the high percentage of setting resulted in the rapid consumption of the endos-

perm. Therefore the average weight of the seedlings in the two lots did not differ very much after 211 days.

Relation of the size of bunches to germination and growth of seedlings

The size of bunches referred to in this paper is the number of nuts borne by the spadix. A bunch with a minimum of ten nuts was considered heavy and that with a maximum of five nuts, light.

Table 4 shows that the means of the two plots varied decidedly only in the number of nuts in the bunch. The difference was 8.3200 $\pm$ 0.0663. The results of the experiment showed that, as a general rule, nuts from heavy bunches germinated earlier than those from light. The mean difference, however, in the daily percentage of germination was not very marked.

The mean differences of the average height and number of leaves, weight of seedlings, and number of roots per seedling were statistically significant in favor of nuts from heavy bunches. The average length of the roots did not show any significant difference. The seedlings grown from seed nuts of heavy bunches grew better than those from nuts of light bunches.

Relation of the percentage of female flower-bearing rachillae to germination and growth of seedlings

A spadix with 30.5 per cent female flower-bearing rachillae and below was considered low; and that with 50.5 per cent and above, high. The seed nuts planted for this experiment were middle nuts taken from the dorsal side of the bunch. All characters considered in this experiment were the same except the percentage of female flower-bearing rachillae. The mean difference between the low and high percentages of female flower-bearing rachillae was 33.00 $\pm$ 1.05 per cent. No significant differences in the means of the percentage of germination of the nuts, average height of leaves, weight of seedlings, and average length of roots in the two groups were found. The nuts in the high percentage of female flower-bearing rachillae germinated earlier than those in the low, with a mean difference of 2.600 $\pm$ 0.715 days. The seedlings grown from seed nuts of the low percentage, however, produced more leaves and roots than those from the high.

The results seem to show that except for the earlier germination of the nuts in the high percentage of female flower-bearing rachillae

and the production of more leaves and roots of the seedlings in the low, the percentage of female flower-bearing rachillae did not influence the other characters under study.

Relation of the weight of nuts to germination and growth of seedlings

Nuts weighing 1.35 kgm. and below were classed as light and those, 1.85 kgm. and above, as heavy.

In this experiment the mean difference of the weights of nuts between the two treatments was significant (0.8060 ± 0.0092). The differences of the other characters considered were significant.

Table 6 shows that the heavy nuts germinated earlier and had a higher percentage of germination than the light. The average height, number of leaves, and number of roots of the seedlings of the heavy nuts were significantly greater than those of the light. The difference, however, in the length of roots was not significant.

The mean difference of the weight of seedlings was not taken into account because before planting a very marked difference existed in the weights of the nuts in the two plots. The difference, however, in the increase of weight of the seedling from a nut was statistically insignificant. Examination of the meat content showed that the meat consumed by the seedlings of light nuts after 211 days was much less than that consumed by those of heavy nuts.

The roots of light nuts were much fewer than those of heavy nuts, the difference being highly significant.

The results showed that in germination of the nuts and subsequent development of the seedlings, heavy nuts were much better than light. The difference in growth of the seedlings in the two lots was very apparent.

Relation of the position of nuts in the bunch to germination and growth of seedlings

The seed nuts used in these experiments differed only in their respective position in the bunch. In one experiment top nuts from the dorsal and ventral sides of the bunch only were used, and the germination of the nuts and the growth of seedlings were compared. In another experiment top, middle, and bottom nuts, dorsally located on the bunch, were used. The germination of the nuts and growth of the seedlings were similarly compared.

Table 7 shows no significant difference exists in the means of the number of days, percentage of germination of the nuts, and the

average height of leaves of the seedlings between the top nuts taken from the dorsal side and those from the ventral side of the bunch. The average number of leaves and the weight of the seedlings were slightly greater in the dorsal than in the ventral nuts. The number of roots per seedling from the dorsal nuts, however, was less than that from the ventral.

Based on the results obtained, the dorsal and ventral positions of the nuts did not seem to have any influence on the germination of the nuts and on the subsequent growth of the seedlings.

Table 8 shows that in the top and bottom nuts, no significant difference existed between the means with respect to earliness and percentage of germination, height and weight of the seedlings, and average length of the roots. More leaves, however, were produced by the seedlings grown from the top nuts.

The middle nuts germinated earlier but showed a lower percentage of germination than the top and bottom nuts. No significant difference was found between the means of the two treatments in weight of seedlings and average length of roots. The seedlings of the top and bottom nuts were slender but slightly taller than those of the middle.

The mean differences in the number of days from planting to germination and the percentage of germination of the middle and bottom nuts were significantly in favor of the middle nuts. The bottom nuts, however, produced taller but slightly more slender seedlings than the middle nuts. No significant difference was observed in weight of seedlings and average length of roots per seedling.

The middle nuts germinated earlier than the top; the latter, however, had a higher percentage of germination and taller seedlings with more leaves.

The results obtained in these experiments showed only one point in favor of the middle nuts; they germinated earlier than either the bottom or the top. The seedlings of the bottom and top nuts were taller.

SUMMARY AND CONCLUSIONS

1. Thin-husked nuts with an average of 2.9 cm. (thickness of husk) and below germinated earlier and produced more seedlings with more leaves and roots than thick-husked nuts of 3.0 cm. (thickness of husk) and above.

2. Seedlings grown from nuts with a setting percentage of 35.5 per bunch and above germinated earlier and gave a higher percent-

age of germination. The seedlings produced had more leaves and longer roots than those from nuts obtained from bunches of a low percentage of setting, 18.5 and below.

3. Nuts gathered from heavy bunches of ten or more likewise germinated earlier and produced seedlings which were taller, heavier, and with a much better root system than those from light bunches.

4. The nuts from bunches with a high percentage of female flower-bearing rachillae (50.5 or more) required less time to germinate and produced slightly taller seedlings than those from bunches with a low percentage. Although the lengths of the roots in the two treatments were practically the same, the seedlings in the latter produced less roots and leaves than those in the former.

5. Light nuts weighing 0.95 to 1.35 kilograms germinated much later than heavy nuts (1.85 to 2.45 kilograms) and produced shorter seedlings with less roots and leaves.

6. The position of the nuts on the bunch, such as on the ventral and dorsal sides, had no influence on the time and percentage of germination. The seedlings of nuts from the dorsal side produced more leaves and were heavier than those from the ventral. The seedlings from the ventral side, however, were taller and developed more roots than those from the other lot.

7. The seedlings from the top nuts produced more leaves and roots than those from the bottom. The middle nuts required less days to germinate but gave a much lower percentage of germination than either the top or the bottom.

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TABLE 1

Basis of selection of nuts for the different plantings [a]

LOT NUMBER AND TREATMENTS	RANGES						
	Percentage of setting	Diameter divided by length	Thickness of husk	Weight of nuts	Percentage of female flower-bearing rachillae	Number of nuts in the bunch	Position in the bunch
	per cent		*cm.*	*kgm.*	*per cent*		
1. Low percentage of setting .	6.50–18.50	0.77–0.94	2.28–3.48	1.35–1.85	2.85–56.50	5.00–10.00	Dorsal top
2. High percentage of setting	35.50–55.50	0.77–0.94	2.28–3.48	1.35–1.85	2.85–56.50	5.00–10.00	Dorsal top
3. Thin-husked nuts	18.50–36.50	0.81–0.96	2.08–2.88	1.35–1.85	38.50–60.50	5.00–10.00	Ventral middle
4. Thick-husked nuts	18.50–36.50	0.81–0.96	3.98–4.78	1.35–1.85	38.50–60.50	5.00–10.00	Ventral middle
5. Nuts from heavy bunches .	16.50–30.50	0.75–0.90	2.88–3.88	1.35–2.05	38.50–60.50	10.00–16.00	Ventral bottom
6. Nuts from light bunches .	16.50–30.50	0.75–0.90	2.88–3.88	1.35–2.05	38.50–60.50	1.00– 5.00	Ventral bottom
7. High percentage of female flower-bearing rachillae ..	10.50–24.50	0.75–0.90	2.88–3.88	1.35–2.05	50.50–80.50	5.00–10.00	Dorsal middle
8. Low percentage of female flower-bearing rachillae ..	10.50–38.50	0.75–0.90	2.88–3.88	1.35–2.05	18.50–30.50	5.00–10.00	Dorsal middle
9. Dorsal nuts	22.50–38.50	0.75–0.90	2.68–3.85	0.95–1.45	26.50–40.50	10.00–16.00	Dorsal top
10. Ventral nuts	22.50–38.50	0.75–0.90	2.68–3.85	0.95–1.45	34.50–60.50	10.00–16.00	Ventral top
11. Light nuts	16.50–32.50	0.81–1.02	2.48–3.48	0.95–1.35	26.50–50.50	1.00– 5.00	Dorsal bottom
12. Heavy nuts	16.50–40.50	0.81–1.02	2.48–3.48	1.85–2.45	26.50–50.50	1.00– 5.00	Dorsal bottom
13. Top nuts	26.50–40.50	0.73–0.94	2.28–3.48	1.65–2.35	32.50–60.50	1.00– 5.00	Dorsal top
14. Bottom nuts	26.50–40.50	0.73–0.94	2.28–3.48	1.65–2.35	32.50–60.50	1.00– 5.00	Dorsal bottom
15. Middle nuts	26.50–40.50	0.73–0.94	2.28–3.48	1.65–2.35	32.50–60.50	1.00– 5.00	Dorsal middle

[a] The two ranges heavily underlined in each column are those of a certain character of the nut whose effects shall be compared.

TABLE 2

Comparison of the means of thin- and thick-husked nuts

CHARACTERS	THIN-HUSKED	THICK-HUSKED	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	6.82 ± 0.0193	6.82 ± 0.2030	0.00 ± 0.0280	Very insignificant
Diameter of nut over its length	0.89 ± 0.0018	0.86 ± 0.0016	0.02 ± 0.0023	Not significant
Thickness of husk in cm.	2.54 ± 0.0059	4.18 ± 0.0648	1.64 ± 0.0657	Very significant
Weight of nut in kgm.	1.55 ± 0.0068	1.55 ± 0.0216	0.00 ± 0.0215	Not significant
Percentage of setting	28.86 ± 0.1247	28.78 ± 0.3332	0.08 ± 0.3550	Not significant
Percentage of female flower-bearing rachillae	47.14 ± 0.1573	48.02 ± 0.1289	0.88 ± 0.2337	Not very significant
Number of days from planting to germination	51.90 ± 0.4585	64.50 ± 0.2520	12.60 ± 0.5540	Very significant
Percentage of germination	51.90 ± 2.9116	65.72 ± 0.1950	13.82 ± 2.9180	Significant
Average height of leaves in cm.	61.90 ± 0.5940	60.36 ± 0.5140	1.54 ± 0.7110	Not significant
Number of leaves	4.78 ± 0.0108	4.52 ± 0.0467	0.26 ± 0.0427	Significant
Weight of seedling in kgm.	1.70 ± 0.0074	1.69 ± 0.0024	0.00 ± 0.0081	Not significant
Number of roots per seedling	6.92 ± 0.0151	6.73 ± 0.0636	0.19 ± 0.0657	Significant
Average length of roots in cm.	35.70 ± 0.3042	29.09 ± 0.7404	6.61 ± 0.8080	Significant

TABLE 3

Comparison of the means of nuts from bunches of high and low setting percentage

CHARACTERS	LOW SETTING PERCENTAGE	HIGH SETTING PERCENTAGE	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	6.80 ± 0.0031	6.30 ± 0.0880	0.50 ± 0.0881	Not very significant
Diameter of nut over its length	0.86 ± 0.0029	0.86 ± 0.0020	0.00 ± 0.0113	Not significant
Thickness of husk in cm.	3.00 ± 0.0194	3.00 ± 0.0186	0.00 ± 0.0268	Very insignificant
Weight of nut in kgm.	1.61 ± 0.0262	1.61 ± 0.0078	0.00 ± 0.0099	Not significant
Percentage of setting	14.94 ± 0.1533	41.30 ± 0.1448	26.36 ± 0.2107	Very significant
Percentage of female flower-bearing rachillae	40.50 ± 0.6744	40.54 ± 0.6717	0.04 ± 0.9440	Not significant
Number of days from planting to germination	61.80 ± 0.6088	57.90 ± 0.4398	3.90 ± 0.7510	Significant
Percentage of germination	67.22 ± 0.4624	71.10 ± 0.4620	3.88 ± 0.6533	Significant
Average height of leaves in cm.	64.72 ± 0.0042	74.94 ± 0.0361	10.22 ± 0.0363	Significant
Number of leaves	4.16 ± 0.0813	4.54 ± 0.0392	0.38 ± 0.0417	Significant
Weight of seedling in kgm.	1.71 ± 0.0074	1.72 ± 0.0051	0.01 ± 0.0173	Not significant
Number of roots per seedling	6.50 ± 0.0298	6.73 ± 0.0341	0.23 ± 0.0427	Significant
Average length of roots in cm.	32.05 ± 0.0904	34.00 ± 0.0294	1.95 ± 0.0948	Significant

TABLE 4

Comparison of the means of nuts from heavy and light bunches

CHARACTERS	LIGHT	HEAVY	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	3.52 ± 0.0020	11.82 ± 0.0329	8.32 ± 0.0663	Very significant
Diameter of nut over its length	0.82 ± 0.0560	0.82 ± 0.0012	0.00 ± 0.0026	Not significant
Thickness of husk in cm.	3.30 ± 0.0029	3.33 ± 0.0247	0.03 ± 0.0262	Not significant
Weight of nut in kgm.	1.63 ± 0.0042	1.62 ± 0.0051	0.01 ± 0.0065	Not significant
Percentage of setting	27.10 ± 0.3010	27.02 ± 0.2474	0.08 ± 0.3888	Not significant
Percentage of female flower-bearing rachillae	47.70 ± 0.3440	46.78 ± 0.3479	0.92 ± 0.4880	Not significant
Number of days from planting to germination	67.20 ± 0.5833	64.29 ± 0.4314	2.91 ± 0.7240	Significant
Percentage of germination	67.22 ± 2.4668	64.70 ± 0.0289	2.52 ± 2.4460	Not significant
Average height of leaves in cm.	64.73 ± 0.0245	74.71 ± 0.0094	9.98 ± 0.0262	Significant
Number of leaves	3.62 ± 0.0323	4.18 ± 0.0616	0.56 ± 0.0697	Significant
Weight of seedling in kgm.	1.73 ± 0.0046	1.77 ± 0.0052	0.04 ± 0.0069	Significant
Number of roots per seedling	5.52 ± 0.0112	7.21 ± 0.0357	1.69 ± 0.0375	Significant
Average length of roots in cm.	31.48 ± 0.0631	31.84 ± 1.1998	0.36 ± 1.1830	Not significant

TABLE 5

Comparison of the means of nuts from bunches of high and low percentage of female flower-bearing rachillae

CHARACTERS	LOW PERCENTAGE	HIGH PERCENTAGE	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	7.36 ± 0.0346	7.54 ± 0.0612	0.18 ± 0.0703	Not significant
Diameter of nut over its length	0.83 ± 0.0020	0.83 ± 0.0028	0.00 ± 0.0021	Not significant
Thickness of husk in cm.	3.27 ± 0.0171	3.27 ± 0.0017	0.00 ± 0.0173	Very insignificant
Weight of nut in kgm.	1.54 ± 0.0012	1.55 ± 0.0003	0.01 ± 0.0012	Not significant
Percentage of setting	18.98 ± 0.2102	18.86 ± 0.1678	0.12 ± 0.2680	Not significant
Percentage of female flower-bearing rachillae	59.58 ± 1.0520	26.58 ± 0.0116	33.00 ± 1.0500	Very significant
Number of days from planting to germination	68.70 ± 0.9620	66.10 ± 0.3222	2.60 ± 0.7150	Significant
Percentage of germination	66.60 ± 0.2480	66.12 ± 0.2682	0.48 ± 0.3604	Not significant
Average height of leaves in cm.	70.50 ± 0.1703	71.47 ± 0.0413	0.97 ± 0.4470	Not significant
Number of leaves	4.68 ± 0.0259	4.23 ± 0.0209	0.45 ± 0.0333	Significant
Weight of seedling in kgm.	1.65 ± 0.1039	1.67 ± 0.0194	0.02 ± 0.1014	Not significant
Number of roots per seedling	7.78 ± 0.0503	6.68 ± 0.0542	1.10 ± 0.0736	Significant
Average length of roots in cm.	29.30 ± 0.7955	29.36 ± 0.8179	0.06 ± 1.1803	Not significant

TABLE 6

Comparison of the means of heavy and light nuts

CHARACTERS	LIGHT	HEAVY	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	3.68 ± 0.0889	3.64 ± 0.8450	0.04 ± 0.8496	Not significant
Diameter of nut over its length	0.95 ± 0.0041	0.92 ± 0.6514	0.03 ± 0.0950	Not significant
Thickness of husk in cm.	3.19 ± 0.0140	3.13 ± 0.0066	0.06 ± 0.0154	Not significant
Weight of nut in kgm.	1.26 ± 0.0013	2.07 ± 0.0091	0.81 ± 0.0092	Very significant
Percentage of setting	23.04 ± 0.4580	23.58 ± 0.4468	0.54 ± 0.6392	Not significant
Percentage of female flower-bearing rachillae	37.42 ± 0.3071	37.86 ± 0.4510	0.44 ± 0.5450	Not significant
Number of days from planting to germination	64.75 ± 0.0531	56.50 ± 0.3816	8.25 ± 0.3830	Significant
Percentage of germination	75.10 ± 1.9600	56.50 ± 0.2724	18.60 ± 2.1400	Significant
Average height of leaves in cm.	70.66 ± 0.1270	74.10 ± 0.0283	3.44 ± 0.1301	Significant
Number of leaves	3.85 ± 0.0129	4.64 ± 0.0322	0.79 ± 0.0349	Significant
Weight of seedling in kgm.	1.28 ± 0.0026	2.21 ± 0.0634	0.93 ± 0.0630	Very significant
Number of roots per seedling	5.60 ± 0.0672	7.76 ± 0.0415	2.16 ± 0.0785	Significant
Average length of roots in cm.	35.00 ± 0.7517	33.90 ± 0.3091	1.10 ± 0.8112	Not significant

TABLE 7

Comparison of the means of dorsal and ventral nuts in the bunch

CHARACTERS	DORSAL	VENTRAL	DIFFERENCE	SIGNIFICANCE
Number of nuts used	50	50		
Number of nuts in the bunch	13.10 ± 0.0202	12.58 ± 0.0644	0.52 ± 0.0675	Not very significant
Diameter of nut over its length	0.82 ± 0.0154	0.82 ± 0.0095	0.00 ± 0.0060	Not significant
Thickness of husk in cm.	3.16 ± 0.0211	3.14 ± 0.0230	0.02 ± 0.0312	Not significant
Weight of nut in kgm.	1.25 ± 0.0021	1.24 ± 0.0014	0.01 ± 0.0010	Not significant
Percentage of setting	31.10 ± 0.5220	31.10 ± 0.2333	0.00 ± 0.5715	Very insignificant
Percentage of female flower-bearing rachillae	44.02 ± 0.1613	44.30 ± 0.2111	0.28 ± 0.2650	Not significant
Number of days from planting to germination	64.16 ± 0.0724	64.07 ± 0.0250	0.09 ± 0.0765	Not significant
Percentage of germination	61.03 ± 0.9800	59.63 ± 0.8397	1.40 ± 1.2810	Not significant
Average height of leaves in cm.	83.07 ± 0.0114	84.29 ± 0.0140	1.22 ± 1.2400	Not significant
Number of leaves	4.51 ± 0.0495	4.41 ± 0.0350	0.10 ± 0.0193	Significant
Weight of seedling in kgm.	1.44 ± 0.0288	1.40 ± 0.0106	0.04 ± 0.0113	Significant
Number of roots per seedling	7.22 ± 0.0136	7.57 ± 0.0809	0.35 ± 0.0822	Significant
Average length of roots in cm.	31.17 ± 0.7651	31.75 ± 0.0351	0.58 ± 0.7707	Not significant

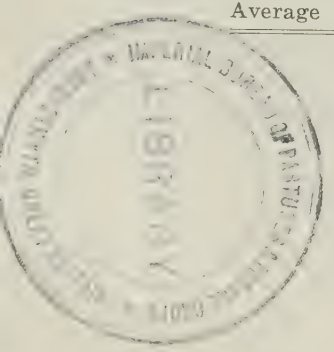

TABLE 8

Comparison of the means of top, bottom, and middle nuts in the bunch

CHARACTERS	TOP	MIDDLE	BOTTOM	DIFFERENCE OF TOP AND BOTTOM	SIGNIFICANCE	DIFFERENCE OF MIDDLE AND BOTTOM	SIGNIFICANCE	DIFFERENCE OF MIDDLE AND TOP	SIGNIFICANCE
Number of nuts used	50	50	50						
Number of nuts in the bunch .	3.62±0.0761	3.26±0.0357	3.58±0.0770	0.04±0.0591	Not significant	0.32±0.0846	Not very significant	0.36±0.0881	Not very significant
Diameter of nut over its length.	0.84±0.0019	0.84±0.0012	0.84±0.0045	0.00±0.0132	Not significant	0.00±0.0096	Not significant	0.00±0.0091	Not significant
Thickness of husk in cm.	3.01±0.0220	3.00±0.0186	3.00 ±0.0205	0.01±0.0306	Not significant	0.01±0.0245	Not significant	0.02±0.0288	Not significant
Weight of nut in kgm.	1.86±0.0037	1.88±0.0048	1.87±0.0021	0.01±0.0042	Not significant	0.01±0.0052	Not significant	0.02±0.0060	Not significant
Percentage of setting	31.22±0.2703	31.23±0.2688	31.18±0.2417	0.04±0.0363	Not significant	0.05±0.3618	Not significant	0.01±0.3818	Not significant
Percentage of female flower-bearing rachillae	42.58±0.0252	43.30± 0.2994	42.34±0.7511	0.24±0.0911	Not significant	0.96±0.8000	Not significant	0.72±0.3810	Not significant
Number of days from planting to germination.	66.90±0.5410	60.80± 0.8350	67.00±0.5430	0.10±0.7660	Not significant	6.20±1.0570	Significant	6.10±1.0560	Significant
Percentage of germination ..	66.94±0.3973	58.50±0.5807	67.00±0.4307	0.06±0.5860	Not significant	8.50±0.7310	Significant	8.44±0.7050	Significant
Average height of leaves in cm. .	74.91±0.0312	69.10±0.4100	73.59±0.0914	1.32±0.0965	Not significant	4.49±0.4195	Significant	5.80±0.4101	Significant
Number of leaves	4.49±0.0141	4.32±0.0266	3.93±0.0171	0.56±0.0499	Significant	0.39±0.0318	Significant	0.17±0.0536	Significant
Weight of seedling in kgm. .	2.01±0.0316	2.07±0.0150	2.02±0.0289	0.01±0.0424	Not significant	0.05±0.0316	Not significant	0.06±0.0352	Not significant
Number of roots per seedling ..	6.37±0.0689	6.48±0.0738	5.34±0.0531	1.03±0.0895	Significant	1.14±0.0932	Significant	0.11±0.1031	Not significant
Average length of roots in cm. ..	33.13±1.0281	32.50±0.9343	30.80±0.3869	2.33±1.1661	Not significant	1.70±1.0049	Not significant	0.63±1.4380	Not significant

VIABILITY OF SOME PHILIPPINE WEED SEEDS [1]

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WITH ONE PLATE

The problem of seed viability has long been of interest to botanists and those engaged in any form of agriculture, especially when it deals with weed seeds. Up to the present no data on the viability of Philippine weed seeds surviving burial or preservation under laboratory conditions are available, whereas in other countries, especially the temperate ones, much work has already been done (Beal, 1884, 1885, 1889a, 1889b, 1894, 1905a, 1905b, 1911; Peter, 1894; Ohga, 1927; Goss, 1924, 1933; Darlington, 1915, 1922, 1931). The present paper, which is a progress report on the viability of some Philippine weed seeds either buried in the ground or stored in vials under laboratory conditions, is based on work conducted in the College of Agriculture, University of the Philippines. It was started in 1933.

MATERIALS AND METHODS

The seeds. During March and April, 1933, seeds of seven species of weed plants, namely, *Amaranthus spinosus* Linn., *Celosia argentea* Linn., *Corchorus olitorius* Linn., *Dactyloctenium aegyptium* (Linn.) Richt., *Elephantopus spicatus* Aubl., *Jussiaea linifolia* Vahl, and *Stachytarpheta jamaicensis* (Linn.) Vahl, all growing in the College of Agriculture, were collected by the writer. They were cleaned and dried in the laboratory, and all empty ones were removed. From the stock, several lots of one hundred seeds taken at random were obtained for each species. These were stored in small vials for a time in the laboratory until they were ready to be buried in the ground on June 10, 1933.

From November 20 to 27, 1933, the writer and Mr. Martin Guerrero, of the School of Forestry, collected seeds of sixteen other weed species, namely, *Abelmoschus moschatus* Medic. var. *haenkeanus* (Presl) Merr., *Ageratum conyzoides* Linn., *Cosmos caudatus* HBK.,

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[2] At present with the Natural History Museum Division, Department of Agriculture and Commerce.

Fimbristylis miliacea (Linn.) Vahl, *Ipomoea triloba* Linn., *Leucaena glauca* (Linn.) Benth., *Melochia concatenata* Linn., *Mimosa pudica* Linn., *Panicum flavidum* Retz., *Portulaca oleracea* Linn., *Sesbania cannabina* (Retz.) Pers., *Sida acuta* Burm. f., *Sida retusa* Linn., *Synedrella nodiflora* (Linn.) Gaertn., *Urena lobata* Linn., and *Vernonia patula* (Dry.) Merr. All of these with the exception of the last, which was collected along the railroad track between Los Baños and Masili, Laguna, were growing on the College of Agriculture campus. Seeds from each species were dried and cleaned as before, and lots of one hundred seeds taken at random were also obtained. Those from each lot were placed temporarily in glass vials as before without any preservative until they were ready to be buried in the ground on December 10, 1933.

On October 10, 1938, the writer came across a box in the laboratory of the Department of Agricultural Botany, College of Agriculture, University of the Philippines, containing seed samples of forty species of weed plants left by Quisumbing (1921) from his work on systematic descriptions of some Philippine weed seeds. These had been collected in 1919, before Dr. E. Quisumbing went to the United States.[3] They had been kept in glass vials with tin covers. Some of the vials contained a small amount of naphthalene, but others had none. Perhaps all the seeds had had naphthalene at one time, but some had probably lost it long before the writer found them. The species represented in the collection were *Alysicarpus nummularifolius* (Linn.) DC. (100),[4] *Amaranthus spinosus* Linn. (40), *Andropogon halepensis* (Linn.) Brot. var. *propinquus* (Kunth) Merr. (100), *Argemone mexicana* Linn. (19), *Bidens leucorrhiza* (Lour.) DC. (21), *Biophytum sensitivum* (Linn.) DC. (25), *Borreria hispida* (Linn.) K. Schm. (83), *Cantharospermum scarabaeoides* (Linn.) Baill. (12), *Cassia alata* Linn. (11), *Coix lachryma-jobi* Linn. (4), *Corchorus acutangulus* Lam. (100), *Corchorus olitorius* Linn. (100), *Cosmos caudatus* HBK. (97), *Crotalaria incana* Linn. (100), *Cyperus difformis* Linn. (100), *Cyperus iria* Linn. (40), *Dactyloctenium aegyptium* (Linn.) Richt. (100), *Eclipta alba* (Linn.) Hassk. (100), *Elephantopus spicatus* Aubl. (21), *Fimbristylis annua* (All.) R. & S. (100), *Imperata cylindrica* (Linn.) Beauv. var. *koenigii* (Retz.) Benth. (24), *Indigofera hirsuta* Linn. (100), *Indigofera suffruticosa* Mill. (100), *Jussiaea linifolia* Vahl (88), *Kyllinga monocephala* Rottb.

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[3] Information supplied by Dr. E. Quisumbing, Chief of Natural History Museum Division, Department of Agriculture and Commerce.

[4] The numbers in parentheses indicate the number of seeds that were germinated by the writer on December 21, 1938.

(100), *Mariscus dilutus* (Vahl) Nees (100), *Merremia gemella* (Burm. f.) Hallier f. (100), *Mimosa pudica* Linn. (100), *Panicum crus-galli* Linn. (100), *Panicum flavidum* Retz. (100), *Panicum repens* Linn. (29), *Paspalum conjugatum* Berg. (100), *Paspalum longifolium* Roxb. (11), *Paspalum scrobiculatum* Linn. (66), *Pericamypylus glaucus* (Lam.) Merr. (13), *Portulaca oleracea* Linn. (100), *Saccharum spontaneum* Linn. subsp. *indicum* Hack. (100), *Scirpus grossus* Linn. f. (100), *Synedrella nodiflora* (Linn.) Gaertn. (100), *Tricholaena rosea* Nees (100), and *Waltheria americana* Linn. (43).

Burial of seeds. The procedure followed in burying the seed samples in the ground was nearly identical to that described by Darlington (1922) and used for the famous experiment on weed seeds by Dr. J. W. Beal at the Michigan Agricultural College, East Lansing, Michigan, U. S. A. The seeds for each species were first mixed thoroughly with a little moderately moist sterilized fine sand and then placed in a glass vial of twenty milliliters capacity. Each vial was filled with sterilized fine sand tamped down lightly, and the mouth was left unstoppered. The vials containing the seeds were placed in a slanting position with their mouths downward (Pl. 1, fig. 1 and 3) in a trench 15.24 centimeters (6 inches) deep. The trench was dug behind the laboratory of the Department of Agricultural Botany Building, College of Agriculture, University of the Philippines, Los Baños, Laguna.

The same procedure was followed with the second set from sixteen species of weed plants. The seeds of *Leucaena glauca* were placed in bottles with a capacity of one hundred milliliters instead of vials because of their size. These bottles were also buried with the rest of the vials in the trench (Pl. 1, fig. 1) on December 10, 1933.

The vials and bottles were placed in rows 12.5 centimeters apart and 6.25 centimeters from each other in the row. The same soil taken from the trench was packed down firmly to cover the containers.

Depth of burial and seed viability. In another experiment seven lots of a hundred seeds each from eleven species of weed plants, namely, *Ageratum conyzoides, Fimbristylis miliacea, Ipomoea triloba, Leucaena glauca, Melochia concatenata, Mimosa pudica, Panicum flavidum, Portulaca oleracea, Sida acuta, Sida retusa,* and *Vernonia patula,* were buried at different depths in an adjoining trench. Seed samples from each species were buried from 7.62 centimeters (3 inches) to 53.34 centimeters (21 inches) from the ground level

(Pl. 1, fig. 2). The containers were buried on December 10, 1933, and were excavated on March 29, 1935, after exactly 449 days. Their viability was then tested.

Digging the samples and testing seed viability. In removing the samples from the ground, the digging had to be done carefully so as not to injure the vials or bottles. None was removed from the trench until all the samples needed had been carefully located and checked. This was done to minimize error in handling.

The method of testing the viability of the weed seeds before burial was as follows: Two hundred seeds taken at random from each of the seven species were put on fine sterilized sand in tin cans. The sand had been sterilized with two per cent mercuric chloride. They were designated the germinators. A thin layer of sand was then placed on top of the seeds and watered daily. The germinators were covered with moist cheese cloth to prevent contamination if possible. All seedlings that germinated for one week after planting and every two days thereafter for a month were counted daily. Records of the seedlings for each species were carefully made (table 1) on June 10, 1933. The test for the second batch of weed seeds was made on December 10, 1933, (table 1) with the same procedure, but with only 100 seeds for each species.

The viability of the experimental seeds after burial was tested by the following procedure: The sand in the vial or bottle was first moistened with tap water. It was loosened with a stiff wire, and a little tap water was again poured into it. Afterwards the contents were emptied into a germinator. The germinators were watered daily as before and covered with moist cheese cloth to prevent contamination. They were inspected daily for one week, every two days thereafter for one month, and weekly for two months. At each inspection every seedling was carefully recorded. After each seedling had been counted, it was pulled off by hand. The sand in the germinator was then stirred with a wire so that those seeds which were buried deep could come nearer the surface to germinate easily.

Seeds stored in glass vials under laboratory condition were not tested for their viability previous to storage; hence, the writer was not able to determine definitely whether they were then viable or not.

Germination tests of the buried weed seeds were made every six months for three to three and one-half years, and yearly thereafter for three years (table 1). In order to carry on the experiment for longer periods, succeeding germination tests would have to be made at intervals of from two to three years.

RESULTS AND DISCUSSION

Results of several germination tests are shown in table 1. The data on the viability tests of the experimental seeds previous to burial were rather variable for every species so that although some showed a surprisingly high percentage of germination (86 per cent), one of them exhibited no germination at all. This was true of *Fimbristylis miliacea,* which exhibited no germination at the start of the experiment but showed sixty-four per cent germination after six months burial in the ground. These variations in the degree of viability of the experimental seeds might have been due to several factors. Perhaps one was that the method employed by the writer in testing their viability did not provide for the optimum conditions for their proper sprouting. Crocker (1938) states that seeds of a number of wild plants showed little or no germination after short burial periods, but considerable to excellent germination after longer periods. These conditions were due to their dormancy or peculiar requirements for germination such as coat scarification, light, and fluctuating temperatures. Although some seeds of species that would perhaps have survived burial showed either no or a small percentage of germination because they were not given the optimum conditions they require, others exhibited remarkably higher percentages of germination because optimum conditions were prevailing. Up to the present, however, the optimum conditions for each sort of seeds have not been found, otherwise they could have been supplied the seeds experimented upon in order to obtain more reliable results than here reported. Besides, one should remember that some species require a rest period after maturation before their optimum germination can be attained.

Results of this study indicated that a little less than half the species tested survived burial for from six to six and one-half years in the ground and to a depth of 15.24 centimeters (6 inches). These were *Ageratum conyzoides, Amaranthus spinosus, Celosia argentea, Corchorus olitorius, Dactyloctenium aegyptium, Melochia concatenata, Mimosa pudica, Portulaca oleracea, Sesbania cannabina, Sida acuta,* and *Stachytarpheta jamaicensis. Elephantopus spicatus* survived burial for four years, and *Abelmoschus moschatus* and *Sida retusa,* for three. *Ipomoea triloba, Jussiaea linifolia,* and *Panicum flavidum* lived for three to three and one-half years. *Leucaena glauca* and *Synedrella nodiflora* were still viable after burial for two years and one year, respectively, although the former did not seem that it would stand burial after a year. *Cosmos caudatus* and *Elephantopus spicatus,* however, were not able to stand burial even for six months.

It is very interesting to note that four species, namely, *Ipomoea triloba, Panicum flavidum, Sesbania cannabina,* and *Sida acuta* showed remains of old sprouts (table 1) in the vials while buried in the ground. The same behavior was observed by Duvel (1905) in *Triticum aestivum, Hordeum sativum, Phaseolus vulgaris, Fagopyrum fagopyrum, Bromus racemosus,* and *Asparagus officinalis.*

Under the conditions then existing in this experiment, weed seeds possess different degrees of tolerance to burial in that although some died within a reasonably short time, others could remain buried in the soil for longer periods and then become active when brought near enough to the surface to get proper combinations of warmth, air, and moisture. Yearly, large amounts of weeds have perhaps grown and germinated because buried weed seeds in temporary pastures, fallow fields, and idle ground have been brought to the surface by plowing. In fact estimates of the amount of weed seeds at various depths in the soil (Pipal, 1916; Robbins and Boyack, 1919) show that the number of weed seeds vary inversely with the depth. Duvel (1905) of the United States Department of Agriculture found that about twenty-five per cent of the species, most of which were weed seeds, still showed a good percentage of germination approximately a year after being buried in the soil and when placed in porous clay pots at Arlington Farm, Virginia. King (1932) found as high as sixty per cent germination of different kinds of weeds and cultivated plants placed four inches below the surface of the ground in a protected place in the fall of 1911. Goss (1924) also found that out of the 107 species of weed seeds buried in the soil in common flower pots at depths of 8 inches, 22 inches, and 42 inches, respectively, 51 were surviving after twenty years. The high vitality of weed seeds buried in the soil has, therefore, been proven beyond any reasonable doubt, so that in the control of weeds, one of the best methods would be to arrest as much as possible the development and maturation of the seeds from them.

The fact that seeds of many wild plants remain in the soil for long periods in a dormant but viable condition means that the soil is always well stocked with seeds which are capable of germination when it is disturbed. This assures the persistence of the species. Also the task of the farmer and gardener in fighting weeds is made difficult, for when the soil is once well stocked with seeds, it takes years of cultivation for the complete germination and final destruction of the weeds.

If the species here presented would be grouped into their respective families, those which survived the six to six and one-half year burial were the following: Gramineae, Portulacaceae, Amaranthaceae, Leguminosae, Verbenaceae, and Compositae.

As stated above, data on tropical weed seeds are wanting as far as the writer could determine. This should make the data in this paper more interesting in demonstrating that in the control of weeds, the plants should not be allowed to grow to maturity and thus produce seeds that may be the source of infestation at some future time.

The influence of depth of burial in the ground has also received some attention. Waldron (1904) found that seeds buried 10 inches deep were better preserved. He attributed this to the uniformity of the temperature in the deeper portions of the soil. Duvel (1905) also found that the deeper the seeds were buried, the better was their vitality preserved. In the present study, however, the treatment given the seven species of weed seeds seemed not to have influenced their vitality after being buried for 449 days (table 2). No correlation of any magnitude was found on the total percentage of viable seeds buried at various depths in the soil. If the individual species would be taken into account, results showed that *Leucaena glauca* seeds were better preserved at a depth of from 22.86 to 38.10 centimeters (9 to 15 inches), *Melochia concatenata* at 15.24 centimeters (6 inches), and *Vernonia patula* and *Mimosa pudica* at 30.48 centimeters (12 inches). The other species showed a nearly uniform percentage of germination at all depths. Therefore, simply plowing under to exterminate the weeds which have gone to seed does not accomplish its purpose. Each plowing of a field previously infested with weed seeds brings some of them nearer to the surface of the ground to begin germination and at the same time buries others more deeply in order to preserve their vitality.

Under laboratory conditions of storage in glass vials provided with naphthalene for a period of nearly 19 years or more, very few of the 40 species hereon given remained viable. Those which survived storage were *Amaranthus spinosus* (4)[5], *Corchorus acutangulus* (40), *Corchorus olitorius* (4), *Dactyloctenium aegyptium* (5), *Mimosa pudica* (2), *Portulaca oleracea* (2), and *Waltheria americana* (1). Becquerel (1907) found that of the 500 species of seeds obtained from the Museum of Natural History at Paris, belonging to 30 families, those from Leguminosae, Nymphaeaceae, Malvaceae, and Labia-

[5] Numbers in parentheses indicate the percentage of germination of the experimental seeds.

tae gave the highest percentage of germination after 87 years of storage. Schjelderup-Ebbe in 1936 (Crocker, 1938) tested the vitality of 1254 batches and nearly as many species of seeds stored in bottles or paper bags for 34 to 112 years. The oldest living sort was that of *Astralgus utriger* Pall., 82 years old, with 6 per cent germination. Some kinds that were not so old showed a relatively high percentage of germination. The following families were represented: Cannaceae, Leguminosae, Euphorbiaceae, Malvaceae, Thymelaeaceae, Convolvulaceae, Solanaceae, and Compositae. Duvel (1905) stated that most seeds stored in the laboratory preserved their vitality much better than those that were buried, but a number of cases were discovered by him where preservation was as good in the soil as in the laboratory.

Turner (1933) stated that seeds collected in the Isle of Wight in 1842 by Dr. Bromfield and those sent to Kew 1851 by Peter and Lawson & Co., were preserved in loosely corked bottles in the Museum. Leguminous seeds as old as 90 years yielded 4 per cent germination, and *Ipomoea* sp., 43 years old, 6 per cent. Seeds of Polygonaceae, Cruciferae, Papaveraceae and Scrophulariaceae failed to germinate.

SUMMARY

This paper presents some pertinent data on the viability of some Philippine buried weed seeds. It is a progress report of an experiment started on June 10, 1933, in the College of Agriculture. It also includes the viability of weed seeds preserved under laboratory conditions in glass vials containing some naphthalene.

A little less than half of the 23 species treated in this paper survived burial to a depth of 15.24 centimeters (6 inches) in the ground for a period of from six to six and one-half years. These were *Ageratum conyzoides* Linn., *Amaranthus spinosus* Linn., *Celosia argentea* Linn., *Corchorus olitorius* Linn., *Dactyloctenium aegyptium* (Linn.) Richt., *Melochia concatenata* Linn., *Mimosa pudica* Linn., *Portulaca oleracea* Linn., *Sida acuta* Burm. f., *Sesbania cannabina* (Retz.) Pers., and *Stachytarpheta jamaicensis* (Linn.) Vahl.

Depth of burial for a period of 449 days showed no apparent influence on the viability of the buried weed seeds under the conditions obtaining in this study.

Of the 40 species of weed seeds preserved under laboratory conditions in glass vials with naphthalene for nearly 19 years or more, only 7 survived; these showed rather a low percentage of germination. They were *Amaranthus spinosus* Linn., *Corchorus acutangu-*

lus Lam., *Corchorus olitorius* Linn., *Dactyloctenium aegyptium* (Linn.) Richt., *Mimosa pudica* Linn., *Portulaca oleracea* Linn., and *Waltheria americana* Linn.

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EXPLANATION OF PLATE

(These drawings were made by Mr. V. V. Marasigan of the Natural History Museum, Department of Agriculture and Commerce).

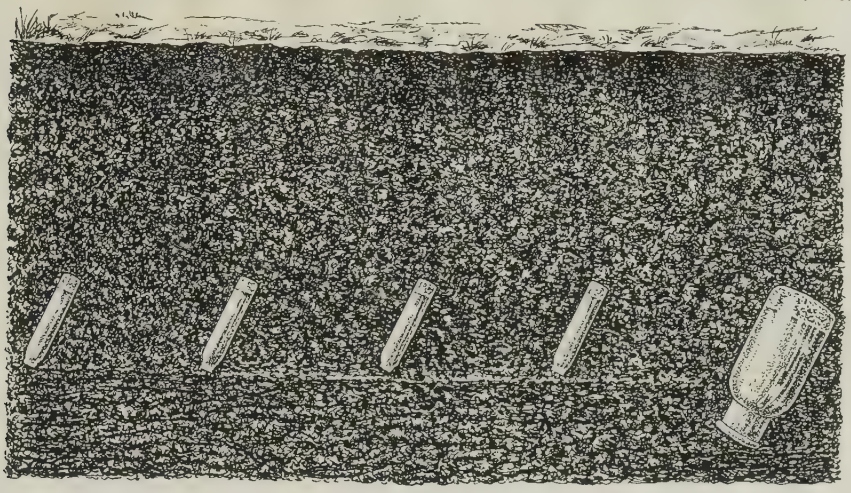
PLATE 1

Fig. 1. Cross-sectional view of the trench showing positions of the receptacles of the experimental seeds. × 1/6.

Fig. 2. Cross-sectional view of the trench where the experimental seeds were buried at different depths. × 1/6.

Fig. 3. Detailed view of a vial containing the experimental seeds. × 1.

Fig. 4. Detailed view of a bottle containing the seeds of *Leucaena glauca* (Linn.) Benth. × 1/2.



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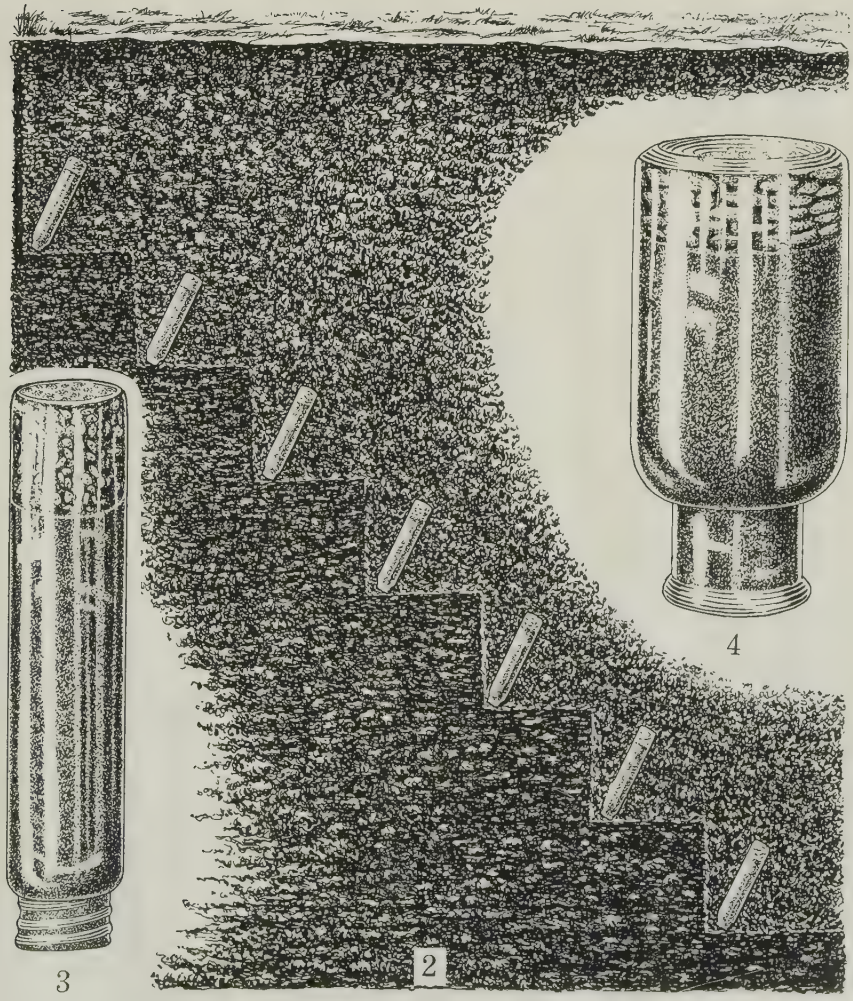

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TABLE 1

Percentages of germination of some Philippine weed seeds before and after burial in the ground

NAME OF SPECIES	INITIAL TESTS BEFORE BURIAL		GERMINATION TESTS AFTER BURIAL									
	6/10/33	12/10/33	12/10/33	6/10/34	12/10/34	6/10/35	1/10/36	6/10/36	12/10/36	12/21/37	12/10/38	12/10/39
Abelmoschus moschatus	—	38	—	50	1	4	0	45	2	0	0	0
Ageratum conyzoides	—	45	—	5	1	75	67	13	23	11	10	15
Amaranthus spinosus	42.25	—	58	79	82	29	66	73	65	15	13	11
Cosmos caudatus	—	85	—	0	0	0	0	0	0	0	0	0
Celosia argentea	42.75	—	28	10	5	95	8	4	22	3	4	5
Corchorus olitorius	54.25	—	54	1	26	58	0	2	0	24	61	75
Dactyloctenium aegyptium	72.25	—	8	66	62	32	50	56	45	26	65	54
Elephantopus spicatus	70.75	—	0	0	0	0	0	0	0	0	0	0
Fimbristylis miliacea	—	0	—	64	11	0	2	32	2	1	0	0
Ipomoea triloba	—	52	—	3	2	29	1 [a]	5	0	0	0	0
Jussiaea linifolia	81	—	50	32	38	0	47	56	0	0	0	0
Leucaena glauca	—	86	—	58	0	1	1	0	0	0	0	0
Mimosa pudica	—	82	—	47	14	23	2	20	0	0	3	5
Melochia concatenata	—	45	—	61	2	21	1	35	3	7	1	2
Panicum flavidum	—	78	—	15	17	41	50 [b]	3	0	0	0	0
Portulaca oleracea	—	12	—	55	32	47	1	17	2	8	1	5
Sesbania cannabina	—	35	—	37	5	45	8 [d]	65	5	12	9	7
Sida acuta	—	54	—	19	9	15 [c]	2	24	1	6	1	3
Sida retusa	—	72	—	27	16	4	0	0	1	0	0	0
Stachytarpheta jamaicensis	78	—	56	55	67	53	17	93	60	46	31	50
Synedrella nodiflora	—	27	—	0	2	0	0	0	0	0	0	0
Urena lobata	—	81	—	13	1	1	0	0	0	3	0	0
Vernonia patula	—	45	—	39	55	44	36	34	1	10	0	0

[a] One seed germinated in the vial.
[b] Fifteen seeds germinated in the vial.
[c] Twenty-eight seeds germinated in the vial.
[d] Two seeds germinated in the vial.

TABLE 2

Behavior of weed seeds buried at different depths in the ground

DEPTH OF BURIAL IN MILLIMETER	NUMBER OF SEEDS THAT GERMINATED FROM ALL LOTS OF 1100 SEEDS	PERCENTAGE OF GERMINATION
7.62	204	18.54
15.24	237	21.54
22.86	185	16.21
30.48	231	21.00
38.10	216	19.63
45.12	373	23.90
53.34	240	21.81

THE COST OF PRODUCING CORN SILAGE AT THE COLLEGE OF AGRICULTURE [1]

JOSÉ P. ESGUERRA
Of the Department of Animal Husbandry

WITH ONE TEXT FIGURE

The first concrete silo of the College of Agriculture was constructed in March, 1928, under President Gonzalez of the University of the Philippines, then Head of the Department of Animal Husbandry. Since then corn silage has been used at this College for cattle and carabaos; however, no determination on the cost of producing it has yet been made. Hence, this study was undertaken.

The object of this work was to determine the cost of producing corn silage at the College of Agriculture. The study was begun in January, 1929, and ended in January, 1939, in the Department of Animal Husbandry.

Land

One and one-fourth hectares were used for the wet season cultures, and one and one-half for the dry. Both areas were used for only six months each time. The land was level and sufficiently well-drained. The soil was deep clay loam. The value was placed at ₱250 per hectare, and the rent at ₱30 a year. The area for the wet season crops was plowed and harrowed during the dry months; that of the dry season crops during the wet.

Silo

The small concrete silo (fig. 1) of the College [2], 8 feet (2.43 meters) in diameter and 27 feet (8.22 meters) in height, was used in this study. The cost of building it was ₱1,151.76. It was calculated to last thirty years. So far on an average, it has been used for six months each year for twelve years.

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[1] Experiment Station contribution No. 1374. Read before the Los Baños Biological Club on August 31, 1939.

Thanks are due Prof. A. B. Catambay of the Department of Agricultural Engineering for his help in determining the life of the machinery and the farm implements used in this study.

[2] ESGUERRA, JOSÉ P. 1932. Construction and operation of silos in the College of Agriculture. The Philippine Agriculturist 21: 318-343.

Labor

The laborers of the Department of Animal Husbandry were employed in plowing, harvesting the crops, and filling the silo. Their wages ranged from ₱0.80 to ₱1.55 a day. The mechanic received ₱2 a day, and the foreman ₱80 a month.

Work animals

Six grade Indian buffaloes were used for preparing the land, cultivating the corn, and drawing the carts. The rate was ₱0.50 each day.

Engines

A Fordson tractor valued at ₱1,923.75 was used to operate the blower-cutter in 1929 and 1933 and to do the first plowing for the 1938-1939 crop. It was used on an average of 60 days a year and was out of commission after 10 years. The filling of the silo in 1937-1938 and 1938-1939 was done with a Diesel engine valued at ₱750.00. It was used twice in one year and only for half a day each time. It was calculated to last 15 years.

Blower-cutter

A Hocking Valley blower-cutter costing ₱995 was operated in 1929 and 1933, but in 1937-1938 and 1938-1939, a McCormick-Deering blower-cutter valued at ₱723 was used. The first cutter was worn out after having been used for 10 years; the second is calculated to last for the same length of time. They were used twice in one year and only for one day each time.

Bull carts

Six bull carts were used for hauling the corn fodder from the field to the silo. The total cost was ₱360. The carts are used on an average of 150 days in one year and are calculated to last four years.

Plows and harrows

A disc plow was used in the preparation of the land in 1938-1939. It cost ₱332.15. The cost of the disc harrow was ₱251.25. The plow was used 60 days a year and the harrow 30 days. The plow was used one day and the harrow one-half day. They were calculated to last 15 years. The land was subsequently plowed with locally made plows costing ₱36. These plows were used 150 days

in one year and lasted 2.5 years. The average use of the plow in this study was four days in the wet and 4.5 days in the dry season.

Fuel

Crude oil was the fuel for the Diesel engine, and kerosene for the tractor.

Seed corn

Yellow Flint variety of corn from Laguna was grown for ensiling.

Cultures

Five crops were grown for this study, three during the wet season and two during the dry season.

Wet season culture. The area for the 1929 crop was first plowed and harrowed on January 12 and 14 and again on June 26 and 27. On May 18, the corn was planted. Five to seven seeds were dropped in each hill. On May 31, the plants were thinned out to only four to the hill. The rows were hilled on June 12. On August 7, the corn was harvested and ensiled.

The crop was first plowed and harrowed for 1933 on March 16 and 17 and again on May 2 and 3. On May 29, the corn was planted, and on June 15, the weak plants were pulled out. The corn was hilled on June 21 and ensiled on August 23.

The area for the 1938 crop was plowed and harrowed on March 25 and 26 and again on May 3. On April 21, the corn was planted, and on May 11, it was thinned. On May 23, it was hilled, and on July 12, harvested and ensiled.

Dry season culture. On October 28 and 29, 1937, the area for the dry season crop was plowed and harrowed. This was repeated on November 17 and 18, and done for the third time on November 27 and 28. On December 2, the corn was planted, and on January 15, 1938, the weak plants were thinned out. On January 27, it was hilled, and on March 21, harvested and ensiled.

The area for the 1938-1939 crop was first plowed and harrowed on August 14 and 15, again on September 20 and 21, and for the third time on October 14 and 15. The tractor was employed for the first plowing and harrowing; however, native plows were used for the succeeding operations. Planting followed on October 19; and on November 9, the weak plants were taken out. On November 21, the corn was hilled; and on January 23, 1939, it was cut and ensiled.

Harvesting

The corn was harvested beyond the glazing stage when the husk and a few of the lower leaves had turned yellow. Gibson [3] stated that harvesting earlier than this stage is not advisable owing to the excess moisture in the plants which makes rather unpalatable silage. On the other hand the ensiling of over-ripe corn leads to spoilage unless a sufficient amount of water is added.

The 1929 crop of the wet season culture was harvested at the age of 82 days, the 1933 crop at 87, and the 1938 crop at 84. The average age of the three crops was 84.5 days.

The 1937-1938 crop of the dry season culture was harvested at the age of 90 days, and the 1938-1939 crop at 99. The average age of the two crops was 94.5 days.

Filling the silo

In 1929 and 1933, the equipment for filling the silo (fig. 1) was mounted one day before filling. The following morning filling started, and the work lasted for eight hours. In the succeeding years, the machine was mounted in the morning while the corn fodder was being hauled to the silo, and the filling took only four hours in the afternoon.

Nineteen men were used to fill the silo during the dry season, and 20 men, during the wet. They were assigned as follows: four men for harvesting during the wet season and three men during the dry, one mechanic for the engine, six men for the carts, four for the blower-cutter, and three for tramping the fodder inside the silo.

Owing to shrinkage during the night following the day of filling, the blower-cutter had to be operated again the next morning for about ten minutes to make up for the shortage.

Trampling the cut fodder

The cut fodder was trampled as soon as it was about one meter deep in the silo. Of the three men used, one handled the distributor, and at the same time sprayed water over the forage with a rubber hose and trampled the fodder in the middle of the silo; the other two trampled the sides paying particular attention to the packing close to the doors. Trampling eliminated the air and made space for more fodder. Air in the silo causes molds to grow and creates a

[3] Gibson, A. E. 1937. Silage. Queensland Agric. Jour. 47: 395.

rise in temperature. Eckles, Oshel, and Magruder[4] pointed out that good silage is produced at a temperature of from 50°F. to 100°F. (10°C. to 47.78°C.).

Fig. 1. Filling the silo at the College of Agriculture. Photograph by the Photographic Division, College of Agriculture.

Sealing the silo

The silo must be sealed at the top in silage making. If it is improperly sealed, the loss of silage from molds is unavoidable. The

[4] ECKLES, C. H., O. I. OSHEL, AND D. M. MAGRUDER. 1916. Silage investigations. Missouri Agric. Exper. Sta. Bull. 22: 22-25.

doors should also be properly sealed so as to reduce the loss of silage to the minimum.

Palay and rice straw were used in sealing the top of the silo. While the silo was being filled, about ten gantas of this cereal were placed in a gunny sack and submerged in water over night. The next day the sack was removed from the water, and the cereal allowed to germinate in it for three or four days.

Before sealing, the corn fodder was trampled again. The rice straw was spread on top, well packed, and the germinating rice spread evenly over it.

The doors were tightly closed by placing pieces of *certainteed* or gunny sacks between the edges of the lids and the sides of the doors.

DISCUSSION OF RESULTS

Labor cost of raising the corn

Table 1 shows the labor cost of raising the corn during the wet and dry seasons.

For 1929, eight men and eight carabaos, costing ₱12.30, were used to plow the area for the first time, and the same number of men and animals plowed a second time at the same cost. Three men and three carabaos made furrows, and five men planted the corn for ₱9.90. Three men later thinned the hills; the cost was ₱3.00. Three men and three carabaos were used in hilling at a cost of ₱4.80. The supervision of the work was done by the foreman. Only one-fourth of his time was credited to this work for he had other activities. The total time spent in the preparation of the land, planting of the corn, thinning, and hilling was five days, making the cost of supervision, ₱3.33. The total cost of raising the corn for this year was ₱45.63.

For 1933, eight men and eight work carabaos plowed and harrowed at a cost of ₱11.80. Seven men and seven carabaos plowed a second time for ₱10.30. Three men and three carabaos made furrows and five men planted the corn for ₱9.40. Four men thinned the hills for ₱3.70. Four men and four carabaos were used in hilling at a cost of ₱5.60. The cost of supervision was ₱3.33. The total cost of raising the corn this time was ₱44.13.

For 1938, eight men and eight carabaos plowed and harrowed; the cost was ₱12. Seven men and seven carabaos plowed a second time at a cost of ₱10.50. Three men and three carabaos made furrows and six men planted the corn for ₱11.10. Three men thinned the hills for ₱3. Three men and three carabaos hilled the corn

for ₱4.60. The cost of supervision was ₱3.33. The total cost of raising the corn was ₱44.53.

The average cost of growing the three crops during the wet season was ₱44.76.

For the 1937-1938 crop, seven men and seven carabaos plowed and harrowed the crop three times for ₱10.30 each time. Three men and three carabaos made furrows and five planted for ₱9.55. Three men thinned out the hills for ₱3.05. Three men and three carabaos hilled for ₱4.55. The cost of supervision was ₱3.33. The total cost of growing the corn was ₱51.38.

The tractor was used when the 1938-1939 culture area was first plowed and harrowed at a cost of ₱17.15. Native plows and carabaos were employed in the succeeding times. Eight men and eight carabaos plowed the second time for ₱12, and seven men and seven carabaos, for ₱10.50. Three men and three carabaos made furrows and six men planted the corn, for ₱12. Four men thinned the hills at a cost of ₱4.05. Four men and four carabaos hilled for ₱6.05. The cost of supervision was ₱3.33. The total cost of growing the corn was ₱65.08.

The average cost of growing the two crops of corn during the dry season was ₱58.23.

The average cost of growing the corn during the dry and wet seasons was ₱51.49.

Because the area for the dry season crops had to be plowed three times to eradicate the weeds, the average cost of growing the corn was higher than that of the wet season by ₱13.47. Also, in the 1938-1939 culture the tractor was used to plow and harrow the field for the first time; hence the preparation of the ground was more expensive than when the native plows were used.

Total cost of raising the corn

Table 2 shows the cost of raising the corn during the wet and dry seasons.

Wet season culture. The average labor cost of raising the corn was ₱44.76. The land rent for six months was ₱18.75. The interest on the investment on plows at six per cent for four days was ₱0.02, and the depreciation, ₱0.37. The cost of seed was ₱0.80. Therefore, the total cost of raising the corn during the wet season was ₱64.70.

Dry season culture. The average labor cost of raising the corn was ₱58.23. The land rent for six months was ₱22.50. The interest on the investment on plows for five days was ₱0.03, and the depre-

ciation, ₱0.43. The interest on the investment on the disc plow for one day was ₱0.33, and the depreciation ₱0.31. The interest on the investment on the disc harrow was ₱0.35, and the depreciation, ₱0.28. The cost of corn seed was ₱0.80. The total cost of raising the corn during the dry season was ₱83.26.

Thus, the average cost of raising the corn during the dry and wet seasons was ₱73.98.

Labor cost of filling the silo

The cost of filling the silo includes the combined costs of man and animal labor from the time the corn was harvested till it was ensiled. Table 3 shows this cost.

The cost of cutting the corn in the wet season was ₱4, and in the dry, ₱3. For loading and carting the corn fodder, the cost was ₱10. Feeding the cutter was ₱4.10. Trampling the cut material took one-half day during the dry season at a cost of ₱1.50. During the wet season the same operation for one day cost ₱3. The mechanic was in charge of the machine during the filling. The cost of mounting and supervision of the machine was ₱3.50 for the wet season and ₱2 for the dry. Supervision of labor cost ₱2.66.

The total cost of filling the silo amounted to ₱27.26 in the wet season and ₱23.26 in the dry. The average for the two seasons was ₱25.26.

Charges on silo, filling equipment, carts, fuel, and miscellaneous

Table 4 shows the interest on the investment on the silo, filling equipment, and carts at six per cent and the insurance at two per cent. The depreciation varied according to the length of usefulness of the different equipment.

The interest on the cost of the silo for six months was ₱34.55, and the depreciation was ₱19.19. The interest on the investment of the blower-cutter for one-half year in the wet season culture was ₱29.85, and in the dry, ₱21.69. The depreciation of the same equipment was ₱49.75 for the wet season and ₱36.15 for the dry. The interest on the cost of the engine for one-half year was ₱22.50, and its depreciation, ₱25. The interest on the cost of the tractor was ₱1.92, and its depreciation, ₱3.20. It was used for one day in one year. The interest on the use of the bull carts was ₱0.14, and the depreciation, ₱0.60.

The insurance charge on the silo and the filling equipment for the wet season culture was ₱40.70, and for the dry, ₱26.24.

The cost of fuel for the Diesel engine was ₱0.30, and for the tractor, ₱1.53.

The miscellaneous charges including the cost of the lubricating oil and grease was ₱0.15.

The total charges were ₱181.58 for the wet season culture and ₱186.51 for the dry; the average for the two cultures was ₱184.05.

Cost of producing the corn silage

Table 5 shows the total cost of producing the corn silage. This includes the raising of the corn, filling the silo, and charges on the silo, filling equipment, fuel, oil, and grease.

The average cost of raising the corn in both the wet and dry season cultures was ₱73.98; of filling the silo, ₱25.26; and the charges on the cost of the silo, filling equipment, fuel, and miscellanous items were ₱184.05. Thus, the average of total cost of producing corn silage was ₱283.29, the cost of the dry season culture being ₱293.03, and of the wet, ₱273.54.

Expressed in percentage, the charges based on the total cost follow: for raising the corn, 26.11 per cent; for filling the silo, 8.92 per cent; and for equipment, and miscellaneous items, 64.97 per cent.

The quantity of silage produced in the different cultures was: 18,000 kilograms in 1929, 15,451 in 1933, 16,600 in 1938, 16,086 in 1937-1938, and 16,296 in 1938-1939, making the average production, 16,486 kilograms or 12.03 tons per hectare. Therefore, at a cost of ₱283.29 to produce 16,486 kilograms of corn silage, the cost of 1,000 kilograms was ₱17.18. Jones and Smith [5] found that the cost of producing corn silage on 152 farms in the State of Missouri was $6.65 (₱13.30) per ton. The use of labor-saving machinery was a factor in reducing cost of filling the silo. According to Morrison [6] the cost of producing corn silage was $3.95 (₱7.90) in Iowa, $5.35 (₱10.70) in Wisconsin, and $4.86 (₱9.72) in New York. These figures were based on a production of 8.2 tons of corn silage per acre (0.4 Ha.) in Iowa, 5.6 tons in Wisconsin, and 9.7 tons in New York for the same area.

SUMMARY AND CONCLUSIONS

A study on the cost of producing corn silage was undertaken in the Department of Animal Husbandry, with the Laguna Yellow

[5] JONES, MACK M., AND DWIGHT D. SMITH. 1931. Silo filling methods and costs. Missouri Agric. Exper. Sta. Bull. 303: 4-32.

[6] MORRISON, F. B. 1939. Feeds and Feeding. 20th. ed., vi + 1050 p., illus. and 7 tables.

Flint variety of corn. Three wet season and two dry season crops were used. The results of the study follow.

1. The labor cost of raising the corn was ₱51.49 of which ₱29.17, or 56.65 per cent, was spent for the preparation of the land; ₱10.45, or 20.30 per cent, for planting the corn; ₱3.39, or 6.58 per cent, for thinning; ₱5.15, or 10.00 per cent, for hilling; and ₱3.33, or 6.47 per cent, for supervision.

2. The total cost of producing the corn was ₱73.98 of which ₱51.49, or 69.60 per cent, was labor cost; ₱20.62, or 27.87 per cent, land rent; ₱1.07, or 1.45 per cent, charges for implements; and ₱0.80, or 1.08 per cent, cost of seed.

3. The cost of filling the silo was ₱25.26 of which ₱10.00, or 39.59 per cent, was for carting and loading; ₱4.10, or 16.23 per cent, for feeding the cutter; ₱3.50, or 13.85 per cent, for harvesting; ₱2.75, or 10.89 per cent, for mechanic service; ₱2.66, or 10.53 per cent, for supervision; and ₱2.25, or 8.91 per cent, for tramping.

4. The charges on the silo, filling equipment, fuel, and miscellaneous items were ₱184.05 of which ₱34.55, or 18.77 per cent, represented the interest on the silo cost; ₱19.19, or 10.43 per cent, the depreciation of the silo; ₱25.77, or 14.00 per cent, the interest on the cost of the blower-cutter; ₱42.95, or 23.34 per cent, the depreciation of the blower-cutter; ₱11.25, or 6.11 per cent, the interest on the cost of the engine; ₱12.50, or 6.79 per cent, the depreciation of the engine; ₱1.60, or 0.87 per cent, the depreciation of the tractor; ₱33.47, or 18.18 per cent, the insurance of the silo and the filling equipment; and ₱2.77, or 1.51 per cent, minor charges.

5. The total cost of producing the corn silage was ₱283.29 of which ₱73.98, or 26.11 per cent, represented the cost of raising the corn; ₱25.26, or 8.92 per cent, the labor in filling the silo; and ₱184.05, or 64.97 per cent, the charges on equipment, cost of fuel, and miscellaneous items.

6. Based on the average production of 16,486 kilograms and at a cost of ₱283.29, the cost of producing one ton of corn silage was ₱17.18.

TABLE 1

Labor cost of raising the corn

NATURE OF WORK	WET SEASON CROP				DRY SEASON CROP			AVERAGE
	1929	1933	1938	Average	1937-1938	1938-1939	Average	
	pesos	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*
First plowing	12.30	11.80	12.00	12.04	10.30	17.15	13.72	12.88
Second plowing	12.30	10.30	10.50	11.03	10.30	12.00	11.15	11.09
Third plowing					10.30	10.50	10.40	5.20
Planting	9.90	9.40	11.10	10.13	9.55	12.00	10.78	10.45
Thinning	3.00	3.70	3.00	3.23	3.05	4.05	3.55	3.39
Hilling	4.80	5.60	4.60	5.00	4.55	6.05	5.30	5.15
Supervision	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33
Total	45.63	44.13	44.53	44.76	51.38	65.08	58.23	51.49

TABLE 2

Total cost of producing the corn

ITEMS	WET SEASON	DRY SEASON	AVERAGE
	pesos	*pesos*	*pesos*
Labor cost of raising the corn	44.76	58.23	51.49
Land rent	18.75	22.50	20.62
Interest on cost of plows	0.02	0.03	0.02
Depreciation of plows	0.37	0.43	0.40
Interest on cost of disc plow	—	0.33	0.17
Depreciation of disc plow	—	0.31	0.16
Interest on cost of disc harrow	—	0.35	0.18
Depreciation of disc harrow	—	0.28	0.14
Cost of seed	0.80	0.80	0.80
Total	64.70	83.26	73.98

TABLE 3

Labor cost of filling the silo

NATURE OF WORK	WET SEASON			DRY SEASON			AVERAGE
	Man labor	Animal labor	Total	Man labor	Animal labor	Total	
	pesos	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*
Harvesting	4.00	—	4.00	3.00	—	3.00	3.50
Carting and loading	7.00	3.00	10.00	7.00	3.00	10.00	10.00
Feeding the cutter .	4.10	—	4.10	4.10	—	4.10	4.10
Trampling	3.00	—	3.00	1.50	—	1.50	2.25
Mechanic service ..	3.50	—	3.50	2.00	—	2.00	2.75
Supervision	2.66	—	2.66	2.66	—	2.66	2.66
Total	24.26	3.00	27.26	20.26	3.00	23.26	25.26

TABLE 4

Charges on silo, filling equipment, carts, fuel, and miscellaneous

ITEMS	WET SEASON	DRY SEASON	AVERAGE
	pesos	*pesos*	*pesos*
Interest on cost of silo	34.55	34.55	34.55
Depreciation of silo	19.19	19.19	19.19
Interest on cost of blower-cutter	29.85	21.69	25.77
Depreciation of blower-cutter	49.75	36.15	42.95
Interest on cost of engine	—	22.50	11.25
Depreciation of engine	—	25.00	12.50
Interest on cost of tractor	1.92	—	0.96
Depreciation of tractor	3.20	—	1.60
Interest on cost of bull carts	0.14	0.14	0.14
Depreciation of bull carts	0.60	0.60	0.60
Insurance of silo and filling equipment	40.70	26.24	33.47
Cost of fuel	1.53	0.30	0.92
Miscellaneous	0.15	0.15	0.15
Total	181.58	186.51	184.05

TABLE 5

Cost of producing corn silage

ITEMS	WET SEASON	DRY SEASON	AVERAGE
	pesos	*pesos*	*pesos*
Cost of producing the corn	64.70	83.26	73.98
Labor cost of filling the silo	27.26	23.26	25.26
Charges on silo, filling equipment, carts, fuel, and miscellaneous	181.58	186.51	184.05
Total	273.54	293.03	283.29

STUDIES ON SULFOFICATION IN SOILS [1]

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Studies on sulfur in relation to soils and crops and on the sulfur oxidation in soils have been carried out on foreign soils. Among them are the works of Brown and Kellogg (1914), Brown and Johnson (1916), Joffe (1921), Powers (1923), Rudolfs (1921), Simon and Schollemberger (1925), Shedd (1919), and Aquino (1931).

Nothing has yet been done on the sulfofying power of Philippine soils as influenced by the moisture content, soil reaction, topographical condition, and other features which might influence their sulfur oxidizing power.

MATERIALS AND METHODS

Samples of soil were collected from five caiñgins, each divided into two lots. They were taken when the field was neither too wet nor too dry.

The samples were collected separately from ten or more representative spots in each of the ten plots by scraping the layer or organic matter off the surface and then digging up the soil to a depth of about six inches (15.4 cm.). Those from the plots were mixed to make a composite sample and placed in labeled cotton bags. When they were brought in the laboratory, they were thoroughly mixed. Following the method of Fred and Waksman (1928), the moisture content of a small portion of each composite sample was determined.

Treatment of the soil samples. One hundred grams of pulverized soil were placed in each of six labeled tumblers and treated as follows:

Tumblers 1-2: Nothing added (check)
Tumblers 3-4: Added 4 grams of sodium thiosulfate
Tumblers 5-6: Added 1 gram of elemental sulfur.

Twenty-five cubic centimeters of distilled water were added to each tumbler, and the contents were mixed thoroughly with a clean glass rod. The tumbler and contents were then weighed.

The cultures were kept in dark chambers for thirty days. At intervals of ten days, they were reweighed in order to determine the loss of moisture from evaporation. The moisture lost was replaced by adding water with a pipette until the original weight of the culture

[1] Experiment Station contribution No. 1375.

was attained. In this way the optimum moisture content of the cultures was fairly well maintained during the incubation period.

The hydrogen ion concentration (pH value) of the soils and of the soil cultures after incubation were determined by the quinhydrone pH indicator.

The quantitative determination of sulfate in each of the cultures was accomplished by the Burgess-Parr turbidimeter.

Description of the plots. The lots situated on the east slope of the Maquiling National Park, were all under the caiñgin system of cultivation. Each was divided into two parts; the upper part was designated plot "A", and the lower, plot "B".

Lot 1 has an area of 869 square meters. The whole lot is covered with five-year old rubber trees (*Hevea brasiliensis* (HBK) Muell-Arg.) intercropped with papaya (*Carica papaya* Linn.), corn (*Zea mays* Linn.), and ginger (*Zingiber officinale* Rosc.). The topography is comparatively steep. The surface soil is a grayish brown residual clay loam. The soil is heavy in texture but quite friable in structure.

The area of lot II is about 1,236 square meters. The topography is slightly rolling. As usual under the type of climate of Los Baños, the lot was planted in crop rotation, with upland rice (*Oryza sativa* Linn.), corn, and mungo (*Phaseolus radiatus* Linn.) in rapid succession during the growing season of the year. The soil is reddish brown clay loam, of residual formation from volcanic dust deposit. The texture is heavy. Because the soil breaks into large clods in summer, it is hard to pulverize.

Lot III has an approximate area of 1,678 square meters. It is fairly sloping on the upper portion and rolling on the lower. The upper part was planted to tobacco (*Nicotiana tabacum* Linn.), and the lower, to different kinds of local vegetables. It was not weeded. This caiñgin did not receive any cultivation before the seed bed was prepared. The weeds were allowed to grow so that the lots was well covered with them throughout the year. The surface soil is slightly reddish brown and of residual formation. The soil is heavy in texture and quite tight in structure.

Lot IV has an approximate area of 2,320 square meters. The topography is fairly sloping on the upper portion and rolling on the lower. It was planted in crop rotation to rice, corn, and beans, in the same way as the rotation given above, but with intercrops of papaya. It was a cut-over area. The soil is brown and heavy but friable in structure.

Lot V has an area of about 2,780 square meters. The topography is sloping throughout. It was planted to upland rice, corn, beans, papaya, ginger, radishes, pechay, and tomatoes, each occupying a different plot. This was the best cultivated and best weeded of the five lots. The soil is grayish and residual in formation. It has a heavy texture but is fairly friable in structure.

RESULTS AND DISCUSSION

The averages of the duplicate determinations of the moisture content, hydrogen-ion concentration, and sulfate production for each of the lots covered in the investigation for the nine different samplings are shown in table 1.

Comparison of the sulfofying power of the soils.

The plots under study differ in topography and slightly in soil characteristics, but all are under the caiñgin system of cultivation.

The results showed that the sulfate content of the soils did not vary much in response to the sampling periods. When these caiñgin soils were treated under laboratory conditions with one gram of flowers of sulfur and four grams of sodium thiosulfate ($Na_2S_2O_3.5H_2O$), the sulfate content in both treatments was found to be 3 to 9 times as much as the untreated samples. This increase shows that a decided variation existed in the sulfur oxidizing power of the soils used in the test.

The addition of elemental sulfur to the soil resulted in the amount of sulfates being 3 to 8 times as much as that in the untreated samples. The soils showed a greater sulfofying ability when sodium thiosulfate was used.

The untreated soils of the different lots did not show a significant variation. The average sulfate contents of these lots were 10.06 mgm. in the "A" portion of the lot and 10.00 mgm. in the "B" portion. The sulfur treated samples were found to contain 47.29 mgm. of sulfur as sulfate in "A" and 48.51 mgm. in "B". When the soils were treated with 4 grams of sodium thiosulfate, 50.21 mgm. of sulfur were produced as sulfate in "A", and 47.22 mgm., in "B". The soils from the "B" portion as shown in table 3 showed a greater sulfofying power than those of the "A" portion.

Topographical features of the field and their probable effects on the sulfofying power of the soil

The results showed that an apparent variation of moisture content existed in the soil of the different lots. The moisture content

of the soil ranges from the lowest, 38.33 per cent for "A" to 38.88 per cent for "B" for lot 1, to the highest, 44.71 per cent for "A" and 49.28 per cent for "B" for lot II. The other lots, V, IV, and III are intermediate in magnitude with the moisture content decreasing in the order in which the lots are named; the greater the angle of inclination of the lot, the less the moisture content.

The moisture content of the soils fluctuated for the different periods of sampling. This phenomenon may be interpreted as due mainly to seasonal variation, topography of the land, and differences in the organic matter content of the soils in the various lots, all of which affect soil conditions. The moisture content did not run parallel with the sulfate production in the soil.

Upon comparison, the lower portion of the lots was found to have a little more moisture than the upper. This difference, although not significant, may be attributed to the slope of the lots. The gravitational water tended to accumulate on the lower portion. No significant relation occurred between the moisture content and the hydrogen-ion concentration (pH values) of the soils of the different lots.

The hydrogen-ion concentration of the soils

The hydrogen-ion concentration pH values of the soils of the different lots, for the most part slightly acidic, did not show a significant variation. The pH values ranged from 6.45 to 6.66 or an average of 6.59 for "A" portion and 6.26 to 6.60 or an average of 6.50 for "B" portion.

In the sulfofication experiment, the soils became somewhat more acidic when the flowers of sulfur was used in the test. The average pH value of all the soils collected from the upper portions of the five lots when treated with flowers of sulfur was 6.06 and the lower portions, 6.08 as compared to 6.59 for the soils of the "A" portion and 6.50 for the "B" portion of the control. This increase in acidity was accompanied by an increase in the sulfate content of the samples. The addition of four grams of sodium thiosulfate to the cultures resulted in an increase in the sulfate content, which was greater than that obtained from the flowers of sulfur treatment. Table 1 shows that the hydrogen-ion concentration decreased. The sodium thiosulfate treated soils of the upper portion of all the lots showed an average pH value of 6.73 and the lower portion, 6.71.

SUMMARY AND CONCLUSIONS

1. Studies were made on the sulfofying power of the soils of five caiñgin areas on the eastern slope of Maquiling National Park as affected by the topography, moisture content, soil reaction, and different methods of management.

2. The soils studied showed a rather high sulfofying power. Soil samples treated with flowers of sulfur showed an increase of sulfate content of from 3 to 8 times as much as the check. A greater sulfofying power resulting in an increase in the sulfate content of soils was observed when sodium thiosulfate was used in the test. With four grams of sodium thiosulfate, the soils of the "B" portion showed a greater sulfur oxidizing power than those of the "A".

3. The moisture content of the soils showed a fluctuation for the different periods of sampling. This phenomenon was due to the seasonal weather variation, topography of the land, differences in the organic matter content, and varied condition of soil management.

4. The moisture content of the soil did not seem to have a very significant influence upon the hydrogen-ion concentration.

5. The addition of flowers of sulfur to the soil brought about a slight increase in the hydrogen-ion concentration, but the application of sodium thiosulfate resulted in the decrease of acidity in the culture.

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TABLE 1

Moisture content, hydrogen-ion concentration, and sulfate production of soils in the various lots [a]

LOT NO.	PERCENTAGE OF MOISTURE		HYDROGEN-ION CONCENTRATION (pH VALUES)						MGM. SULFUR AS SULFATE IN 100 GRAMS OF AIR DRY SOIL					
			Control		Treatments				Control		Treatments			
					1 gram sulfur		4 grams $Na_2S_2O_3.5H_2O$				1 gram sulfur		4 grams $Na_2S_2O_3.5H_2O$	
	A [b]	B [c]	A	B	A	B	A	B	A	B	A	B	A	B
I	38.33	38.88	6.66	6.58	6.03	6.05	6.60	6.48	11.11	10.68	49.02	48.22	53.88	48.16
II	44.71	49.28	6.45	6.26	6.05	6.09	6.57	6.66	9.58	9.68	47.80	45.39	49.37	44.85
III	43.21	42.74	6.61	6.60	6.11	6.12	6.84	6.88	9.37	10.29	42.68	51.11	47.65	49.22
IV	40.32	44.00	6.64	6.60	6.15	6.15	6.88	6.77	10.45	10.03	45.83	51.61	49.32	46.22
V	38.85	41.63	6.57	6.47	5.98	5.98	6.78	6.74	9.75	9.32	47.25	46.23	50.89	47.45
Average	41.08	43.31	6.59	6.50	6.06	6.08	6.73	6.71	10.05	10.00	47.29	48.51	50.21	47.22

[a] Averages of duplicate determinations for nine different sampling periods.
[b] Upper slope of the plot.
[c] Lower slope of the plot.

TABLE 2

Average moisture content, hydrogen-ion concentration, and sulfofication of caiñgin soils [a]

	AVERAGE MOISTURE CONTENT	HYDROGEN-ION CONCENTRATION (pH VALUES)			MGM. SULFUR AS SULFATE IN 100 GRAMS SOIL SAMPLE		
		Control	Treatments		Control	Treatments	
			1 gram sulfur	4 grams $Na_2S_2O_3.5H_2O$		1 gram sulfur	4 grams $Na_2S_2O_3.5H_2O$
	per cent						
A [b]	41.08 ± 0.85	6.59 ± 0.02	6.06 ± 0.02	6.73 ± 0.04	10.05 ± 0.21	47.29 ± 0.77	50.21 ± 0.60
B [c]	43.31 ± 1.15	6.50 ± 0.04	6.08 ± 0.01	6.71 ± 0.04	10.00 ± 0.15	48.51 ± 0.84	47.22 ± 0.51

[a] Averages of duplicate determinations for nine sampling periods.
[b] Upper slope of the plot.
[c] Lower slope of the plot.

TABLE 3

A comparison of average moisture content, hydrogen-ion concentration, and sulfofication of caiñgin soils

	DIFFERENCE	
Percentage moisture:		
A vs. B	2.23 ± 1.42	Insignificant
Hydrogen-ion concentrations:		
A Control vs. B Control	0.09 ± 0.04	Insignificant
A (1 gram S treatment) vs. B (1 gram S treatment)	0.02 ± 0.02	Insignificant
A (4 grams S treatment) vs. B (4 grams S treatment)	0.02 ± 0.05	Insignificant
A (Control) vs. A (1 gram S treatment)	0.53 ± 0.03	Very significant
A (Control) vs. A (4 grams S treatment)	0.14 ± 0.04	Significant
A (1 gram S treatment) vs. A (4 grams S treatment)	0.67 ± 0.04	Very significant
B (Control) vs. B (1 gram S treatment)	0.42 ± 0.04	Very significant
B (Control) vs. B (4 grams S treatment)	0.21 ± 0.05	Significant
B (1 gram S treatment) vs. B (4 grams S treatment)	0.63 ± 0.04	Very significant
Mgm. sulfur as sulfate in 100 gram soil sample:		
A (Control) vs. B (Control)	0.05 ± 0.26	Insignificant
A (1 gram S treatment) vs. B (1 gram S treatment)	1.22 ± 1.14	Insignificant
A (4 grams S treatment) vs. B (4 grams S treatment)	2.99 ± 0.78	Significant
A (Control) vs. A (1 gram S treatment)	37.24 ± 0.80	Very significant
A (Control) vs. A (4 grams S treatment)	40.16 ± 0.63	Very significant
A (1 gram S treatment) vs. A (4 grams S treatment)	2.92 ± 0.98	Insignificant
B (Control) vs. B (1 gram S treatment)	38.51 ± 0.85	Very significant
B (Control) vs. B (4 grams S treatment)	37.22 ± 0.53	Very significant
B (1 gram S treatment) vs. B (4 grams S treatment)	1.29 ± 0.98	Insignificant

CORN-TAPILAN SILAGE AS SUPPLEMENT TO PASTURE FOR RANGE CATTLE DURING THE SUMMER MONTHS [1]

RAMON G. MERCADO

With the increasing interest in the raising of livestock, our pastures apparently must be utilized to the fullest advantage. In the summer months the growth of pasture plants is far below that of the rainy season. Thus in summer the pastures become depleted as a result of overgrazing. In order to prevent this, they should be supplemented with some form of feed such as silage.

In most of the leading agricultural districts of the United States, silage is of great importance. During winter it is cheaper than roots, and in summer, than soiling crops. Now that the Department of Animal Husbandry of the College of Agriculture has succeeded in preparing silage, one of the questions is, could silage be used as a supplementary feed during the summer?

Esten and Mason (1912) recommended mixing a legume with corn to raise the protein content of silage. They asserted that three parts of corn to two parts of cowpeas or soybeans make an excellent combination.

Morrison (1938) states that owing to the great palatability of silage, the animals eat large amounts of it; hence more nutrients are available for milk and flesh production. Besides, silage has a beneficial laxative effect, and aids in keeping stock thrifty.

Miller and Courtice (1927) give the following advantages of silage:

> "1. Silage furnishes an excellent feed for use at any time of the year.
> 2. Ensiling corn reduces the losses and waste through fermentation and weathering.
> 3. In the form of silage the entire plant is consumed; whereas, 20 to 35 per cent of dry corn fodder is usually rejected by stock.
> 4. It is possible to ensile the crop when weather conditions will not permit proper curing of the crop.
> 5. Weedy crops which would make poor hay or fodder will make fair to good silage; the weed seeds being killed by the ensiling process.
> 6. Crops from a given area can be stored in less space as silage than as dry fodder; also it will be in convenient form for feeding.
> 7. Surplus feed can be carried over from one year to another and thus help out during years of scanty feed supply."

[1] Experiment Station contribution No. 1376. Prepared in the Department of Animal Husbandry under the direction of Associate Professor Valente Villegas.

Ward (1914) reported that silage is first among all roughages for finishing cattle, in effecting large daily gains and producing a glossy coat and a soft, pliable skin on the animals. It can be used profitably as a supplement to pastures for steers during drought.

The object of this work was to find whether corn-tapilan silage can be used as a supplementary feed for range cattle during the summer months by (*a*) ascertaining the amount and cost of the silage eaten by the animals and by (*b*) determining the comparative gains in weight of the animals fed on the pasture only and of those supplemented with silage.

The work was done in the Department of Animal Husbandry, College of Agriculture from March, 1936, to June, 1937.

Animals

Twelve head of purebred Nellore cattle varying from one year and four months to nine years and ten months were used. They were divided into two lots with five females and one bull in each. The weight varied from 168.7 kgm. to 391.5 kgm. The average was 323.2 kgm. for lot I and 323.1 kgm. for lot II. The average age of the animals in lot I was five years and three months and in lot II, four years and eleven months.

Pasture and supplement

A common pasture, eight hectares, was provided for the animals of both lots. The predominating species of grasses in this pasture consisted of approximately forty per cent of cogon [*Imperata cylindrica* (Linn.) Beauv. var. *koenigii* (Retz.) Benth.], and a mixture of Bermuda grass [*Cynodon dactylon* (Linn.) Pers.], paraguis [*Eleusine indica* (Linn.) Gaertn.], and carabao grass, or kulape (*Paspalum conjugatum* Berg.)

The weeds encroaching on the stand of grass in the order of their abundance were: sambong [*Blumea balsamifera* (Linn.) D. C.], balatong aso (*Cassia tora* Linn.), payang-payang lalake [*Desmodium pulchellum* (Linn.) Benth.], payang-payang babae [*Flemingia strobilifera* (Linn.) R. Br.], and magilik (*Premna cumingiana* Schauer).

Corn-tapilan silage, ensiled on August 25, 1936, was used as a supplement for animals in lot II.

Barn

For animals in lot II stalls of concrete flooring with stanchions were used. The manger was partitioned so as to prevent the mixing of feeds for the different animals. The barn had an iron roofing and was open on all sides.

General plan of the experiment

Animals of lots I and II were allowed to graze together in a common pasture. Two pastures were provided to allow for rotation; each division was used for one month. Aside from the pasture feed, animals of lot II received corn-tapilan silage as supplementary feed every afternoon in the barn.

Feeding animals in lot II

A preliminary feeding period of twenty days was provided to accustom the animals in lot II to handling, and to determine the amount of silage eaten daily. Following this, the animals in lot II were given the supplement from January 30 to June 19, 1937, a period of 140 days.

During the experimental period, the animals in lot II were given definite quantities of silage each day. The left-over was determined and deducted from the quantity given to obtain the amount eaten by each animal daily. The animals were given all they would take in an hour. After being fed for this length of time, they would refuse any more silage.

Salting and watering

Each animal received about a handful of salt once a week at weighing time. All of them could get water from a creek in the pasture.

Weighing

The average weight of the first three days before the experimental period was taken as the initial weight of each animal. During the experimental period the weights of all animals were taken every Saturday afternoon before those in lot II received their supplement. At the end of the experiment the final weight was taken in the same way as the initial.

Preparation of corn-tapilan silage

Preparation of the field. A field one and three fourths hectares in area was used. This was plowed twice and then harrowed. The field was plowed first on March 11 and 12, 1936, and next on March 23 to 25, 1936. It was harrowed on April 13 and 14, 1936, and again on April 28, 1936. The furrows were then made.

Planting. Three to four seeds of tapilan were planted in alternate hills with those of corn 40 cm. apart in rows one meter apart. Tapilan was planted on May 11 and 12, 1936, and corn on June 1, 1936.

Cultivation. The field was weeded by plowing between the rows. Two weeks after planting, the weeds near the hills were pulled up by hand.

Cutting. The corn and tapilan plants were cut by bolo on August 24, 1936, a little less than three months after planting. At this time the kernels had reached the glazing stage, and the husk and a few of the lower leaves of the corn plants had turned yellow. According to Standler, Jones, Turner, and Bernard (1930), this is the best stage for making corn silage. The average height of the corn at this time was 197.4 cm. The tapilan had an average length of 349.1 cm. then but still had no flowers.

Ensiling. The forage was hauled to the silo and cut by a silage cutter into about two-centimeter lengths the following day. From the cutter, it was forced into the silo by the blower. There it was spread out evenly and trampled to pack it well. Care was taken that the material at the sides of the wall was well pressed. Because the forage was somewhat dry, water was added as it dropped from the blower.

After all the forage had been placed in the silo, a layer of rice straw, 60 cm. thick, was spread on it.

At the top, about 10 kgm. of palay, which had been soaked in water the previous night, was allowed to germinate for the purpose of reducing spoilage to the minimum.

Basis used for computing the cost of producing silage

Rental value of land. The rental value of the land was computed at the rate of 7 per cent on the basis of ₱225 per hectare for six months' use.

Depreciation of silo. The depreciation of the silo in one year was based on its cost, amounting to ₱1,151.76, with its usefulness assumed as lasting thirty years. The depreciation was computed to be 3.53 per cent per year.

Depreciation of the silage cutter. Depreciation of the silage cutter was computed at the rate of 6.25 per cent a year for a period of six months.

Height of cogon in the pasture

The stand of cogon in the pasture was determined by marking six quadrates, each one meter square. They were situated in places where the animals generally grazed. The quadrates were marked with short stakes placed close to the ground so as not to close off the grass from the animals. Twenty cogon plants in each quadrate were measured every two weeks.

Production of corn-tapilan forage

The total amount of forage produced from 1.75 hectares of field used in this study amounted to 23,587.0 kgm. or 13,478.29 kgm. per hectare.

RESULTS AND DISCUSSION

Proportion of tapilan to corn

Six samples weighing 100 kgm. each of corn-tapilan forage were examined to determine the proportion by weight of tapilan to corn. The weight of tapilan ranged from 32.4 kgm. to 38.7 kgm., whereas that of corn was from 61.3 kgm. to 67.6 kgm. The average ratio was 34.1 kgm. of tapilan to 65.9 kgm. of corn forage or one part of tapilan to 1.93 parts of corn by weight.

Cost of production of corn-tapilan forage

Table 1 shows the cost of production of corn-tapilan forage. The total cost of producing 23,587.0 kgm. of fresh corn-tapilan forage was ₱56.65 or ₱32.38 per hectare. The most expensive item was plowing. With the expenses of first and second plowing added, the sum amounted to ₱21.85 or ₱12.49 per hectare. This was 38.56 per cent of the total cost. The rent of land, amounting to ₱15.75 or ₱9.00 per hectare and representing 27.82 per cent of the total cost, was second to plowing. The planting of corn and tapilan cost ₱9.20 or ₱5.26 per hectare, or 16.23 per cent of all costs. The expenses of

cultivation were ₱5.65 or ₱3.23 per hectare, amounting to 9.98 per cent of all expenses. Harrowing incurred the lowest expense, amounting to ₱4.20 or ₱2.40 per hectare. This was 7.41 per cent of the total cost.

Corn-tapilan silage production

Table 2 shows the amount of good and poor silage produced. Of the 23,587.0 kgm. of fresh corn-tapilan forage, only 17,744.8 kgm. of silage were produced; hence the shrinkage amounted to 24.77 per cent. Of the 17,744.8 kgm. of silage, 83.58 per cent or 14,830.7 kgm. were good. The remainder, amounting to 2,914.1 kgm., was spoiled; this represented 16.42 per cent of the total amount. Spoilage occurred both as a result of the growth of white mold and rotting as shown by the dark color and bad odor of the silage. Most of the rotting was along the wall near the door of the silo. Frandsen (1913) also states that the spoiling of silage is due either to white mold or black rot. Black rot is caused by improper packing.

Computed on the hectare basis, the total amount of silage produced was 10,139.89 kgm., or 8,474.69 kgm. of good and 1,665.20 kgm. of spoiled.

Cost of production of corn-tapilan silage

Table 3 shows the cost of production of corn-tapilan silage. The total cost was ₱180.47 or ₱103.14 per hectare. The largest item of cost was the production of corn-tapilan forage, which was ₱56.65 or ₱32.38 per hectare, representing 31.39 per cent of the total cost. The wages for laborers employed in cutting, hauling, and feeding the forage to the silage cutter were second in cost, being ₱41.34 or ₱23.62 per hectare, which is 22.91 per cent of the total cost. The depreciation of the silo amounted to ₱38.39 per year or ₱21.94 per hectare per year, representing 21.27 per cent of all expenses. The depreciation of the silage cutter was ₱31.09 or ₱17.77 per hectare, which is 17.23 per cent of all costs. For fuel the expenses were ₱9.00 or ₱5.14 a hectare. This is equivalent to 4.98 per cent of the total expenses. For work animals used in hauling the forage from the field to the silo, the charges were ₱4.00 or ₱2.29 a hectare. This is 2.22 per cent of the total cost. Based on the amount of good silage produced, the cost of one kilogram amounted to ₱0.012 or ₱12.20 per ton. Morrison (1938) reported that in studies on Iowa farms from 1925 to 1927, the cost of producing corn silage was $3.95 or ₱7.90 per ton.

Analysis of corn-tapilan silage

The proximate analysis of five samples of corn-tapilan silage taken from time to time during the feeding period shows that the average moisture content was 76.81 per cent; fats, 0.54 per cent; ash, 1.82 per cent; proteins, 1.14 per cent; crude fiber, 6.49 per cent; and nitrogen-free extract, 13.20 per cent. The number of calories per 100 grams was 63.80.

Consumption

Actual consumption. The amount of corn-tapilan silage eaten by the animals during the 140 days feeding period is shown in table 4. The consumption ranged from 147.8 kgm. to 212.4 kgm. a head for each period of four weeks. The average amount eaten per head by periods was as follows: first, 147.8 kgm.; second, 180.1 kgm.; third, 188.2 kgm.; fourth, 212.4 kgm.; and fifth, 180.5 kgm. Table 4 also shows that the consumption of silage increased from the first to the fourth periods as summer months advanced and started to decrease as the grasses began to grow again at the beginning of the rainy season. The six animals ate a total of 5,454.0 kgm. of silage during the feeding period of 140 days. Animal 42 ate the greatest amount of silage, which was 1,276.5 kgm., and animal 70, the least, amounting to only 202.6 kgm. On the average the consumption was 909.0 kgm. per head during the whole period.

Average daily consumption. The average daily consumption of silage by the animals varied from 5.3 kgm. to 7.6 kgm. per head daily in the different periods of four weeks. By periods per head, it was as follows: for the first, 5.3 kgm.; the second, 6.4 kgm.; the third, 6.7 kgm.; the fourth, 7.6 kgm.; and the fifth, 6.5 kgm. The average for all animals throughout the whole period was 6.5 kgm. per head daily.

Daily consumption of silage per 100 kgm. live weight. The average daily consumption of silage was from 1.6 kgm. to 2.1 kgm. per 100 kgm. live weight in the different periods of four weeks. During the first period, the average daily consumption per 100 kgm. live weight was 1.6 kgm. a head; the second, 1.8 kgm.; the third, 1.8 kgm.; the fourth, 2.1 kgm.; and the fifth, 1.7 kgm. The average consumption per 100 kgm. live weight during the whole period was 1.8 kgm. daily.

Cost of silage consumed by the animals. The cost of silage consumed by the animals is shown in table 5. The average cost by period was from ₱1.80 to ₱2.59 per head. By periods it was as follows: first, ₱1.80; second, ₱2.20; third, ₱2.30; fourth, ₱2.59; and fifth, ₱2.20. The cost of silage a day for each period ranged from ₱0.064 to ₱0.093 per head. During the first period the cost per head a day was ₱0.064; the second, ₱0.079; the third, ₱0.082; the fourth, ₱0.093; and the fifth, ₱0.079. The total cost of silage eaten during the whole period varied from ₱2.47 with animal 70 to ₱15.56 with animal 42; the average cost per head was ₱11.09. The total cost of silage eaten by the six animals for the whole period was ₱66.51.

Weights of animals

Gain or loss in weight of animals by periods. The gain or loss in weight of the animals taken at the end of the four-week intervals during the 140 days feeding period is shown in table 6. During the first period, three animals in lot I lost in weight; the rest gained. Animal 54 lost the most, amounting to 28.6 kgm., whereas 52 lost the least, 8.6 kgm. Animal 41 lost 21.7 kgm. Animal 68 gained 1.3 kgm.; 64, 8.6 kgm.; and 72, 12.7 kgm. On the whole, during the first period the animals in lot I, which did not receive silage, lost on an average 6.1 kgm. All the animals except one in lot II, which received the supplement, gained in weight. Animal 70 which lost 13.3 kgm. behaved peculiarly, although it looked healthy, and refused to take silage at the beginning of the feeding period. The range in gain of animals in lot I was from 2.7 kgm. with animal 242 to 29.9 kgm. with 42. Animal 62 increased 8.6 kgm.; 66, 5.9 kgm.; and 49, 5.5 kgm.

On the average, both lots gained in weight at the end of the second period. Lot I gained on an average, 5.1 kgm., and lot II, 17.6 kgm., a difference of 12.5 kgm. in favor of lot II. In lot I two animals lost in weight; animal 54 lost 4.5 kgm. and animal 68, 12.7 kgm. The remaining four animals gained in weight ranging from 6.8 kgm. with animal 41 to 16.3 kgm. with animal 64. Animal 72 gained 13.6 kgm. and 52, 10.9 kgm. No loss in weight occurred among the animals in lot II. The gains ranged from 5.0 kgm. with animal 49 to 32.6 kgm. with 242. The rest of the animals gained the following: animal 70, 27.2 kgm.; 62, 16.3 kgm.; 66, 12.7 kgm.; and 42, 11.8 kgm.

At the end of the third period, both lots gained in weight; the average gains were about the same in each. Lot I gained an average

of 9.1 kgm., and lot II, 8.5 kgm. In lot I only animal 72 lost in weight, amounting to 2.7 kgm. The gains ranged from 0.9 kgm. with animal 68 to 24.5 kgm. with 54. The rest of the animals gained the following: animal 64, 19.1 kgm.; 41, 8.1 kgm.; and 52, 4.5 kgm. In lot II all the animals gained in weight, ranging from 3.6 kgm. with animals 62 and 49 to 14.6 kgm. with 242. The other animals gained as follows: animal 66, 12.7 kgm.; 70, 10.0 kgm.; and 42, 6.3 kgm.

Both lots lost in weight at the end of the fourth period, but lot 1 lost much more than the other. At this time, the latter part of April and the beginning of May, the grasses in the pasture lacked succulence and palatability. The average loss in weight in lot I was 14.7 kgm., and in lot II, 5.1 kgm. Silage feeding prevented much loss in weight among the animals in lot II. In lot I four animals lost in weight; the other two gained. The losses ranged from 21.7 kgm. with animal 41 to 35.4 kgm. with 54. Animal 52 lost 22.6 kgm., and 64, 30.0 kgm. On the other hand animal 72 gained 3.7 kgm., and 68, 18.2 kgm. All the animals in lot II, except 242, which gained only 1.8 kgm., lost in weight. The losses ranged from 2.7 kgm. with animal 70 to 12.7 kgm. with 49. Animal 62 lost 9.0 kgm.; 42, 4.5 kgm.; and 66, 3.6 kgm.

At the end of the fifth period, in June, after the rains had come, all animals of both lots gained in weight; the average gains were about the same in both groups. New shoots of grass had sprung up. The average gain was 27.8 kgm. in lot I and 26.3 kgm. in lot II. The gain in weight in lot I ranged from 15.4 kgm. with animal 54 to 44.5 kgm. with 64. The rest of the animals gained as follows: animal 68, 40.8 kgm.; 41, 25.4 kgm.; 52, 24.5 kgm.; and 72, 16.3 kgm. In lot II the gains ranged from 10.9 kgm. with animal 62 to 56.2 kgm. with 242. The rest of the animals gained the following: 70, 34.4 kgm.; 66, 21.8 kgm.; 42, 19.1 kgm.; and 49, 15.4 kgm.

At the end of the feeding period both lots made average gains in weight. Lot I gained 21.2 kgm., and lot II, 53.9 kgm. The difference was 32.7 kgm. in favor of lot II. In lot I, animal 41 lost 3.1 kgm. in weight, and 54, 28.6 kgm. The rest gained in weight, ranging from 8.7 kgm. with animal 52 to 58.5 kgm. with 64. Animal 72 gained 43.6 kgm., and 68, 48.5 kgm. All the animals in lot II gained in weight, ranging from 16.8 kgm. with 49 to 107.9 kgm. with 242. The rest of the animals made the following gains: 42, 62.6 kgm.; 62, 30.4 kgm.; 66, 49.5 kgm.; and 70, 55.6 kgm.

Height of cogon in quadrates

The average height of cogon ranged from 14.43 cm. to 19.73 cm.; the average throughout the whole period was 16.60 cm. The height of cogon did not vary much except in the month of May. Hence the pastures must have been adequate in desirable vegetation, for nowhere during the experiment was the cogon short. Therefore, the unfavorable influence on the animals at certain periods may be attributed to the unpalatability of semi-dry pasture feed and to the bad effects of the dry, warm climate.

SUMMARY AND CONCLUSIONS

From the results of the work on corn-tapilan silage as supplementary feed to pasturage for Nellore cattle, the following conclusions are presented:

1. The amount of corn-tapilan forage produced from one hectare of land was 13,478.29 kgm. The proportion was one part by weight of tapilan to 1.93 parts of corn.

2. The total cost of producing corn-tapilan forage from one hectare of land was ₱32.38. In relation to the total expenses, the cost of the different operations, in percentage including the rent of land, is as follows: plowing, 38.56 per cent; rent of land, 27.82 per cent; planting of corn and tapilan, 16.23 per cent; cultivation, 9.98 per cent; and harrowing, 7.41 per cent.

3. On the hectare basis, the yield of good corn-tapilan silage was 8,474.69 kgm., representing 83.58 per cent of the total amount. The amount of spoiled silage produced was 1,665.2 kgm., which is 16.42 per cent of the total amount. The shrinkage amounted to 24.77 per cent.

4. The cost of producing corn-tapilan silage from one hectare of land was ₱10.31. Computed on the basis of good silage, the cost of one kilogram of the material was ₱0.012, which is equivalent to ₱12.20 per ton.

5. The different factors that affected the total cost expressed in percentage are as follows: production of forage, 31.39 per cent; laborers for cutting forage and feeding it to silage cutter, 22.91 per cent; depreciation of silo, 21.27 per cent; depreciation of silage cutter, 17.23 per cent; fuel, 4.98 per cent; and work animals for hauling forage, 2.22 per cent.

6. The average chemical analysis of corn-tapilan silage is as follows: moisture, 76.81 per cent; fats, 0.54 per cent; ash, 1.82 per cent; proteins, 1.14 per cent; crude fiber, 6.49 per cent; nitrogen-free extract, 13.20 per cent; and calories per 100 grams, 63.80.

7. The average consumption of corn-tapilan silage by the animals in lot II varied from 147.8 kgm. to 212.4 kgm. a head for a period of four weeks. The average consumption a head for a period of 140 days was 909.0 kgm. The average daily consumption of corn-tapilan silage by the animals ranged from 5.3 kgm. to 7.6 kgm. a head. The average for all was 6.5 kgm.

8. The daily consumption of silage per 100 kgm. live weight during the whole period was 1.8 kgm. on an average.

9. The average cost of corn-tapilan silage eaten by the animals for a period of four weeks was from ₱1.80 to ₱2.59 a head. The average was ₱2.22. The total cost of silage eaten throughout the whole period of 140 days was on an average of ₱11.09 a head.

10. At the end of the experiment, animals fed corn-tapilan silage as supplement gained 32.7 kgm. more a head than those feeding on the pasture only. Animals on the pasture without the supplement lost more during unfavorable warm, dry days than those receiving corn-tapilan silage as supplement.

11. The average height of cogon ranged from 14.43 cm. to 19.73 cm.; the average throughout the whole period was 16.60 cm. The pasture did not suffer from overgrazing, although the grasses appeared to lack succulence and palatability during the warmer and drier part of the summer months.

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TABLE 1

Cost of production of corn-tapilan forage

ITEMS	ACTUAL COST	COST PER HECTARE	PERCENTAGE OF TOTAL COST
	pesos	*pesos*	
1. First plowing	10.55	6.03	18.62
2. First harrowing	2.80	1.60	4.95
3. Second plowing	11.30	6.46	19.94
4. Second harrowing	1.40	0.80	2.46
5. Planting	9.20	5.26	16.23
6. Cultivation	5.65	3.23	9.98
7. Rent of land	15.75	9.00	27.82
Total	56.65	32.38	100.00

TABLE 2

The amount of good and poor silage produced

ITEMS	ACTUAL PRODUCTION	PRODUCTION PER HECTARE	PERCENTAGE
	kgm.	*kgm.*	
1. Total amount of corn-tapilan forage placed in silo	23,587.00	13,478.29	100.00
2. Shrinkage	5,842.20	3,338.40	24.77
3. Total amount of silage drawn from the silo	17,744.80	10,139.89	100.00
4. Amount of good silage	14,830.70	8,474.69	83.58
5. Amount of spoiled silage	2.914.10	1,665.20	16.42

TABLE 3

Cost of production of corn-tapilan silage

ITEMS	ACTUAL COST	COST PER HECTARE	PERCENTAGE OF TOTAL COST
	pesos	*pesos*	
1. Cost of production of corn-tapilan forage	56.65	32.38	31.39
2. Expenses for laborers used in cutting and hauling of forage and feeding of forage to cutter	41.34	23.62	22.91
3. Expenses for work animals in hauling	4.00	2.29	2.22
4. Fuel cost	9.00	5.14	4.98
5. Depreciation of silage cutter	31.09	17.77	17.23
6. Depreciation of silo	38.39	21.94	21.27
Total	180.47	103.14	100.00
Cost to produce 1 kgm. of good silage	0.012		

TABLE 4

The silage consumption of the animals at four-week intervals during the 140-day feeding period

ANIMAL NUMBER	PERIODS					TOTAL
	1st (Jan. 30 to Feb. 27)	2nd (Feb. 28 to Mar. 27)	3rd (Mar. 28 to Apr. 24)	4th (Apr. 25 to May 22)	5th (May 23 to June 19)	
	kgm.	*kgm.*	*kgm.*	*kgm.*	*kgm.*	*kgm.*
42	248.2	273.2	261.6	266.3	227.2	1,276.5
49	179.4	196.4	182.6	215.8	170.0	944.4
62	182.8	182.6	164.8	209.2	179.0	918.4
66	129.2	172.5	192.0	229.4	188.4	911.5
70	36.2	28.5	44.7	45.4	47.8	202.6
242	111.0	227.4	283.4	308.4	270.8	1,201.0
Average	147.8	180.1	188.2	212.4	180.5	909.0

TABLE 5

Cost of silage eaten by the animals at 4-week intervals during the 140-day feeding period

ANIMAL NUMBER	PERIODS					TOTAL
	1st (Jan. 30 to Feb. 27)	2nd (Feb. 28 to Mar. 27)	3rd (Mar. 28 to Apr. 24)	4th (Apr. 25 to May 22)	5th (May 23 to June 19)	
	pesos	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*
42	3.03	3.33	3.19	3.25	2.77	15.56
49	2.19	2.40	2.23	2.63	2.07	11.52
62	2.23	2.23	2.01	2.55	2.18	11.20
66	1.58	2.10	2.34	2.80	2.30	11.12
70	0.44	0.35	0.55	0.55	0.58	2.47
242	1.35	2.77	3.46	3.76	3.30	14.64
Total	10.81	13.18	13.78	15.54	13.20	66.51
Average	1.80	2.20	2.30	2.59	2.20	11.09
Average daily cost	0.064	0.079	0.082	0.093	0.079	

TABLE 6

Gain or loss in weight in kilograms of animals at end of 4-week intervals during 140-day feeding period

ANIMAL NUMBER	INITIAL WEIGHT	END OF FIRST PERIOD (Jan. 30 to Feb. 27)		END OF SECOND PERIOD (Feb. 28 to Mar. 27)		END OF THIRD PERIOD (Mar. 28 to Apr. 24)		END OF FOURTH PERIOD (Apr. 25 to May 22)		END OF FIFTH PERIOD (May 23 to June 19)		GAIN OR LOSS AT END OF EXPERIMENT
		Weight	Gain or loss	Weight	Gain or loss	Weight	Gain or loss	Weight	Gain or loss	Weight	Gain or loss	
Lot I (Without supplement)												
41	327.9	306.2	—21.7	313.0	6.8	321.1	8.1	299.4	—21.7	324.8	25.4	— 3.1
52	389.6	381.0	— 8.6	391.9	10.9	396.4	4.5	373.8	—22.6	398.3	24.5	8.7
54	357.0	238.4	—28.6	323.9	— 4.5	348.4	24.5	313.0	—35.4	328.4	15.4	— 28.6
64	304.4	313.0	8.6	329.3	16.3	348.4	19.1	318.4	—30.0	362.9	44.5	58.5
72	168.7	181.4	12.7	195.0	13.6	193.3	— 2.7	196.0	3.7	212.3	16.3	43.6
68	391.5	392.8	1.3	380.1	—12.7	381.0	0.9	399.2	18.2	440.0	40.8	48.5
Average	323.2	317.1	— 6.1	322.2	5.1	331.3	9.1	316.6	—14.7	344.4	27.8	21.2
Lot II (With supplement)												
42	360.2	390.0	29.9	401.9	11.8	408.2	6.3	403.7	— 4.5	422.8	19.1	62.6
49	326.1	331.6	5.5	336.6	5.0	340.2	3.6	327.5	—12.7	342.9	15.4	16.8
62	329.8	338.4	8.6	354.7	16.3	358.3	3.6	349.3	— 9.0	360.2	10.9	30.4
66	337.0	342.9	5.9	355.6	12.7	368.3	12.7	364.7	— 3.6	386.5	21.8	49.5
70	212.0	198.7	—13.3	225.9	27.2	235.9	10.0	233.2	— 2.7	267.6	34.4	55.6
242	373.8	376.5	2.7	402.1	32.6	423.7	14.6	425.5	1.8	481.7	56.2	107.9
Average	323.1	329.7	6.6	347.3	17.6	355.8	8.5	350.7	— 5.1	377.0	26.3	53.9

LEAF BLIGHT OF TOMATO [1]

CHALERM SAIYANANDA AND M. S. CELINO
Of the Department of Plant Pathology

WITH FOUR TEXT FIGURES

In 1936, Roldan described *Helminthosporium lycopersici* on tomato in the Philippines. In March, 1939, a leaf blight of tomato was widespread in the Los Baños Economic Garden of the Bureau of Plant Industry as well as in the vicinity of the College of Agriculture. As it was present on many plants, it was feared that it might develop into a destructive disease and affect tomato growing. Hence, a study was made to determine: (*a*) the cause of the disease, (*b*) the injury to the crop, and (*c*) its occurrence in the field. The experiments were conducted in the Department of Plant Pathology, College of Agriculture, Los Baños, Laguna, from April, 1939, to May, 1940. Observations on the occurrence of the disease were also made on the tomato plantings of the College as well as on the tomato crops of the Los Baños Economic Garden and nearby home gardens.

THE DISEASE

History, distribution, and economic importance

Ellis and Everhart (1897) reported a *Helminthosporium* on decaying tomatoes in Kansas, U. S. A. Seymour (1929) lists *H. tomato* Ell. and Barthol., and *H. rhopaloides* Fres. on tomato in North America. In 1936, in Los Baños Roldan found on tomato an undescribed fungus which he named and described as *H. lycopersici.*

Ellis and Everhart (1897) reported the presence of a *Helminthosporium* on decaying tomatoes in Kansas, U. S. A. Seymour (1929) lists *H. tomato* Ell. and Barthol., and *H. rhopaloides* Fres. on tomato in North America but does not give the economic importance of each species. In 1936, in Los Baños Roldan found on tomato an undescribed fungus which he named and described as *H. lycopersici.*

Up to the present, not much is known about the *Helminthosporium* disease of tomato although it is perhaps present wherever tomato is grown. However, it probably does not cause sufficient injury to the crop to attract attention.

Symptoms

The disease infects tomato plants when they are young. Younger leaves are more severely attacked than older ones. In the early

[1] Experiment Station contribution No. 1377. Prepared in the Department of Plant Pathology under the direction of Associate Professor G. O. Ocfemia.

stage of the disease, the infected areas appear in the form of minute water-soaked circular spots. These gradually increase in size and become pale brown. Very often several spots coalesce to form a much larger and irregular diseased area, which with age becomes more or less circular in shape (fig. 1).

Fig. 1. A young stage of infection on a leaf of tomato caused by *Helminthosporium lycopersici* Roldan. Photograph by the Photographic Division, College of Agriculture.

As the disease advances, more and more of the leaves are infected and blighted (fig. 2). Owing to the development of conidiophores and conidia on both surfaces of the diseased areas, the lesions change with age from brown to grayish brown. During rainy days the infected leaves rot, but on dry days they dry and hang downward

on the plant. Later they fall to the ground and rot. On account of premature death of the leaves, diseased plants either fail to bear fruit or die. In severe infection the stems of the plants are also attacked, and on these, spots similar to those on the leaves, but more elongate, are produced.

Fig. 2. An advanced stage of infection on a leaf of tomato caused by *Helminthosporium lycopersici Roldan.* Photograph by the Photographic Division, College of Agriculture.

CAUSAL ORGANISM

Morphology

Mycelium. The young mycelium is thin-walled, branched, hyaline, and septate. The old hyphae are light to olive brown, granular,

branched, septate, and slightly constricted at the septa (fig. 3a). The cells of the hyphae vary from 10.2 to 44.2μ in length and from 3.4 to 6.8μ in width; the average is 27.2 $\times$ 5.1μ.

Conidiophores. The conidiophores are simple, thick-walled, septate, erect or flexuous, light brown, and have granular contents at the tip (fig. 3b). They arise singly or in clusters from either side of the leaf but more often from the nether side (fig. 3b). They measure from 45.9-105.4μ $\times$ 5.1-6.8μ; the average is 75.7 $\times$ 5.9μ. The conidiophores of *Helminthosporium lycopersici* Roldan (1936) range from 70-145 $\times$ 7-9μ.

Conidia. The conidia are borne apically on the conidiophores or on knee-like projections of aërial hyphae that function as conidiophores. The conidia are light brown, fusoid-cylindrical, clavate to obclavate, obtuse at the ends, thin-walled, granular, continuous to eight-septate, and slightly constricted at the septa (fig. 3c). They are 20.4 to 78.2μ in length and 5.1 to 11.9μ in width; the average is 49.3 $\times$ 8.5μ. The conidia of *Helminthosporium lycopersici* Roldan (1936) are 4- to 12-septate and 50-107 $\times$ 10-18μ. Here again it may be noted that the writers' figures are smaller than those of Roldan. The size of the conidia reported by the writers is based on measurements of 200 conidia.

Germination of conidia and production of spores in culture. The spores germinated on drops of potato-dextrose agar in van Tieghem cells or hollow ground slides. Germ tubes were generally produced at both ends of the spores (fig. 3d), although they have also been observed to come out from any of the other cells of the spores. In a few cases, the septa of the conidia became indistinct before the protrusion of the germ tube; in others, only the septa near the ends seemed to disappear.

The hyphae which arose from the germ tubes began to form conidiophores with conidia at their tips thirty-six to forty-eight hours after germination of the spores on drops of potato-dextrose agar in hollow ground slides.

Cultural studies

The growth of the fungus on different media and substrates was studied, and the results obtained are summarized below:

Potato-dextrose agar. The fungus produced thick and well developed mycelial growth, which appeared gull gray [2] in the first week. The mycelium turned olive the second week, dark olive gray in the

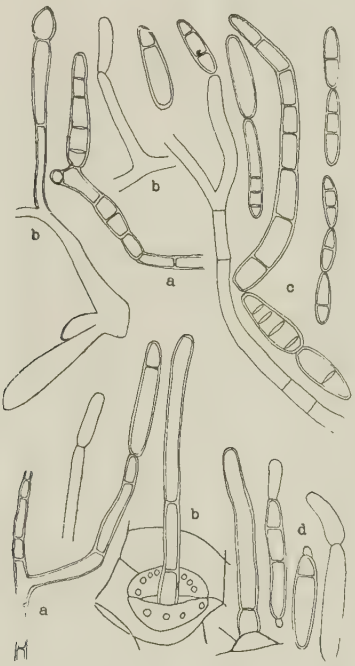

Fig. 3. *Helminthosporium lycopersici* Roldan showing: *a.* mycelium, *b.* conidiophores, *c.* conidia, and *d.* germinating conidia. All drawings were made by the senior author with a camera lucida. × 350.

third, and mouse gray in the fourth. Conidia were readily produced. The submerged mycelium appeared dark.

Water agar. The fungus produced a very poor growth on this medium. The hyphae appeared pale gull gray after the second week and pale olive gray after three weeks. Only a few spores were produced even after one month.

[2] The color names used in this study are those of RIDGWAY, R. 1912. Color standards and color nomenclature. 43 p., *53 colored pl.; 1115 named colors.* Washington, D. C.

Corn meal agar. The mycelium appeared fairly thick, but very few spores were produced after one week. The color was pale gull gray at first but later turned dark natural gray. The mat of the mycelium changed to light mouse gray. More spores were produced after the third and fourth weeks.

Oatmeal agar. The mycelium was thin and pale gull gray after one week but turned pale olive gray after two and four weeks. The conidia were scarce after two weeks, but the number of spores increased considerably after four weeks.

Sterilized Irish potato plugs. The fungus grew profusely and produced a thick mat of mycelium after four weeks. The growth appeared pale gull gray with age and produced numerous conidia.

Sterilized sweet potato cylinder. The organism produced a fairly thick and luxuriant development of mycelium. The growth changed from deep to dark olive gray after two weeks. Conidia were produced abundantly.

Sterilized avocado cylinder. The organism produced a thick and profuse growth of mycelium. As in the other culture media and substrates, the mycelium changed from deep gull to deep olive gray after three weeks and to dark olive gray after four. A fairly large number of conidia were produced.

Sterilized pods of sword beans (*Canavalia gladiata* [*Jacq.*] DC.). The fungus grew profusely and produced a thick growth after one week. Although only a few conidia were produced at first, the number increased considerably after the second week. The aërial hyphae changed from light to gull gray in the first week and to mouse gray after four weeks.

Sterilized tomato stem. The fungous growth appeared pale gull to light olive gray. The mycelium grew fast, and a large number of conidia was produced after four weeks.

Sterilized eggplants. Blocks of sterilized eggplant fruit were a good substrate for the production of abundant spores and a thick growth of the mycelium. The aërial hyphae changed from pale gull to mouse gray. Conidia were produced after two weeks, and more spores appeared after four weeks.

Other sterilized plant tissues, such as ampalaya (*Momordica charantia* Linn.) fruit cylinders, cabbage petioles, string bean pods, and radish root cylinders were used as substrates in the growth of the fungus.

The results of the cultural studies show that the tomato *Helminthosporium* produced varying amounts of growth on different culture media and sterilized substrates. The potato-dextrose agar was the best culture medium, and water agar, the poorest. Of the sterilized plant tissues sweet potato cylinder, Irish potato cylinder, sword bean, ampalaya, cabbage, eggplant, and radish were among the best; these were followed by string bean and tomato stem. The avocado fruit was the poorest.

Spores were produced on most of the culture media and sterilized plant substrates after two weeks.

Growth of the fungus on potato-dextrose agar of varying pH concentrations. The fungus was grown on potato-dextrose agar of varying pH concentrations. For adjusting the reactions of the media, varying amounts of separately sterilized 0.04216 N hydrochloric acid and 0.03577 N sodium hydroxide were added under aseptic conditions to dissolved and sterilized potato-dextrose agar in the test tubes. The pH concentrations of the media were adjusted to pH 3.8, 4.4, 5.0, 6.8, 7.4, and 8.4 with the colorimetric method using a La-Motte Universal Outfit.

The potato-dextrose agar of different pH concentrations was poured into each sterile Petri dish. When the agar congealed, each Petri dish was inoculated at the center with a bit of mycelium of the tomato *Helminthosporium* taken from a young culture. The Petri dish cultures were kept for observation for a few days in the laboratory.

Figure 4 shows that practically no growth was produced by the fungus on potato-dextrose agar with pH concentrations of 3.8 and 4.4. A good growth was produced on the medium with a pH concentration of 5.0. The growth gradually increased as the acidity of the culture media decreased. The rate of growth of the fungus appeared to increase with the pH concentration of the medium within the limits tried in this study. It is not known if pH 8.4 represents the optimum reaction of the medium because the fungus was not grown on more alkaline media.

Taxonomy

In the present paper the writers consider provisionally at least, the causative fungus of the leaf blight of tomato in the Philippines, similar to, if not identical with, *H. lycopersici* Roldan (1936).

Pathogenicity

The pathogenicity of *Helminthosporium lycopersici* on tomato was determined as follows: (*1*) Leaves of tomato seedlings were smeared with spores and mycelium of the fungus together with small bits of potato-dextrose agar. The controls were smeared with potato-dextrose agar only. (*2*) The experimental plants were atomized with a spore-suspension of the fungus in sterile water. The controls were sprayed with sterile water.

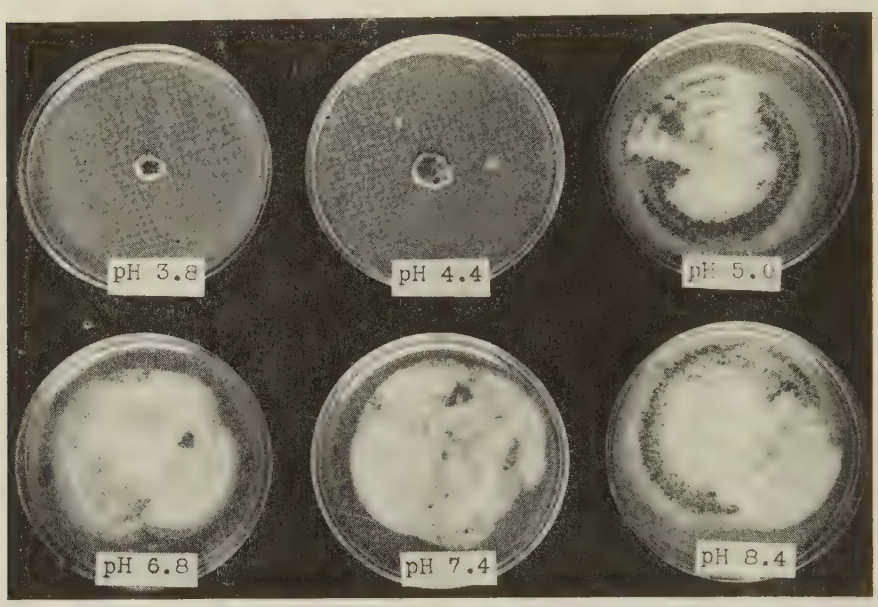

Fig. 4. The growth of *Helminthosporium lycopersici* Roldan on potato-dextrose agar adjusted to different pH concentrations. The fungous growth on the agar medium with a reaction adjusted to pH 3.8 and pH 4.4 was practically inhibited. A luxuriant growth of mycelium was produced on the agar medium with reactions varying from pH 5.0 to 8.4. Photograph by the Photographic Division, College of Agriculture.

The inoculated and the check plants in each case were placed in moist chambers for two or three days. After seventy-two hours in the moist chamber the plants were placed outside under partial shade for observation.

Experiment 1. On August 15, 1939, three tomato seedlings grown from seeds in sterilized garden soil in cans were inoculated according to method (1). Three seedlings were atomized with a spore-suspension of the fungus as in method (2). Two other plants were set aside and used as control for these two experiments.

On August 18, 1939, the sprayed seedlings showed symptoms of infection. Minute water-soaked spots appeared on the leaves and stems of the tomato plants. These spots were circular at first, but they increased in size and finally became oval in shape with age. By running together, several spots occupied a large portion of the leaves and produced blight. The disease progressed rapidly under humid conditions and caused the death of many of the leaves and subsequently of the seedlings.

The seedlings, which were inoculated by smearing the leaves with spores and mycelium of the fungus, also showed similar spots with brown, irregular, and distinct borders. Infection was conspicuous on both sides of the leaves and on the stems. The infected areas dried out, and owing to severe infection, the seedlings died.

The control plants appeared healthy from the beginning to the end of the experiment.

The fungus was reisolated and the resulting cultures were used in the subsequent experiments.

Experiment 2. On September 14, 1939, twenty tomato seedlings, about two months old, were inoculated as in experiment 1. Ten seedlings were smeared with spores and mycelium of the fungus together with bits of the agar media, and ten others were atomized with a spore-suspension of the fungus. Four healthy seedlings were used as controls for the two sets of experiments.

Results similar to those in experiment 1 were obtained. All of the plants inoculated by smearing the leaves with the inoculum died; only three of those atomized with a spore-suspension of the fungus survived infection. As in experiment 1, all of the control plants remained healthy and the fungus was reisolated from the diseased tissues.

Experiment 3. On November 10, 1939, two seedlings of eggplant, two of tobacco, two of pepper, and two of potato were atomized with a spore-suspension of the fungus, and the inoculated plants were treated as in the preceding experiments. Check plants were similarly provided. Of these plants only the eggplant and pepper showed numerous small, irregular, brownish spots on the lower surfaces of the leaves three days after inoculation. The lesions, however, did not increase in size as much as those on tomato leaves. The infection did not spread to the succeeding leaves, as the foliage that appeared later was free from the disease.

Experiment 4. On April 15, 1940, experiment 3 was repeated using two seedlings of eggplant, two of tobacco, two of pepper, and two of potato. As in experiment 3, only the eggplant and pepper seedlings developed slight infection on the leaves; however, none of these plants died.

Method of dissemination

From their field observations the writers believe that the spores of *Helminthosporium lycopersici* are disseminated by the wind and by water splashed during rainy days.

Method of infection

Four tomato seedlings were sprayed with a spore suspension of *Helminthosporium lycopersici* on January 8, 1940, and placed in the damp chamber. Sections were taken from the leaves and strips from portions of the stem after twelve, twenty-four, thirty-six, and forty-eight hours. The leaf sections and strips of the stem were placed in a 50-50 mixture of glacial acetic acid and 95 per cent alcohol to decolorize the tissues. After twenty-four to thirty-six hours, the materials were removed from the decolorizing solution, washed in 50 per cent alcohol, and then stained following the method for differential staining of fungous and host cells described by Vaughan (1914).

A number of sections showed the tips of young fungous hyphae penetrating the leaf through the stomata. In a few instances, the fungous hyphae directly penetrated the epidermis. These were observed especially on the upper surface of the leaves where only a few stomatal pores were evident.

Method of tiding over adverse conditions

Marquez (1923) observed that the conidia of *Helminthosporium* blight of corn remained viable on the leaves as long as three months when kept in the laboratory. Likewise, Mitra (1923) noted that ninety per cent of the spores of the same fungus taken from the dry infected leaves after four months germinated when placed in drops of water and incubated in a moist chamber. After eight months, however, the spores rapidly lost their viability.

On June 15, 1939, a number of spores were obtained from diseased tomato leaves kept in a closed glass container in the laboratory for two and one-half months. These spores germinated readily when placed on a small amount of potato-dextrose agar in hollow ground slides.

On September 10, 1939, spores of the same fungus taken from diseased leaves kept in the laboratory for about six months were similarly treated. A number of the conidia failed to germinate after thirty-six hours. The conidia of the fungus obtained from infected plants after somewhat over a year old did not germinate. No infection was produced on tomato plants planted in sterilized soil mixed with infected stems and leaves of tomato which had been previously kept in the laboratory for about a year.

The writers noted that in the dry state the spores of *Helminthosporium lycopersici* can remain viable on infected tomato leaves for about six months. Under conditions prevailing in Los Baños the fungus can easily exist in the field from season to season in the form of spores and mycelium.

OCCURRENCE OF THE DISEASE IN 1939

Under conditions prevailing in Los Baños in 1939 the writers noted that *Helminthosporium lycopersici* infected tomato plants in the field as early as June and July. The disease increased in severity and appeared destructive during the wet months of that year. Fortunately, tomatoes are not raised extensively during the wet period. Infected tomato plants were found on scattered plants in the vicinity of the College of Agriculture during the months of February and March, 1940. The disease, however, was not found during the period covered by this study on any of the tomato plantings of the College of Agriculture. It was not found in the field during April, 1940, probably on account of the dry condition and high air temperature.

The writers further noted that the disease attacked introduced American varieties of tomato; it was seldom noted on native tomatoes in the field. In the inoculation experiments in which the following five American varieties, namely, Marglobe, Dwarf Giant, Matchless, True Giant Ponderosa, and Sunny-brook Earlina, and one native variety of tomatoes were used, the writers noted that the disease was destructive on all of them.

CONTROL MEASURES

As all varieties of tomato used in this study showed about the same degree of susceptibility to infection, the disease should be controlled by prompt removal and destruction of all infected parts of the plants. Collecting and burning infected leaves of tomato, eggplant, and pepper during the tomato season instead of allowing these

materials to drop to the ground and rot will help minimize the amount of inoculum in the field. As the fungus tides over adverse conditions in the field on previously infected plants, the field should be cleaned at the end of the tomato season.

Pepper and eggplants are only slightly affected by the disease, but potato and tobacco are not affected at all. In case of severe infection, any of these plants or any suitable substitute may be planted instead of tomato.

In the present state of the disease, it will not pay to use spray mixtures for its control.

SUMMARY

1. A *Helminthosporium* disease of tomato was noted in Los Baños Economic Garden and in the vicinity of the College of Agriculture in March, 1939.

2. The symptoms produced on tomato leaves consist of minute water-soaked roundish lesions of pale brown circular spots when young, and blighting or drying of the leaves with age.

3. The fungus produced good growth on potato-dextrose agar and on sterilized sweet potato cylinders, Irish potato cylinder, sword bean, ampalaya, cabbage, eggplant, raddish, string bean, and tomato stem. Its growth on potato-dextrose agar with a hydrogen-ion concentration of pH 3.8 and 4.4 was exceedingly slow. It attained a maximum growth on agar with hydrogen-ion concentrations of pH 7.4 and pH 8.4.

4. The fungus is provisionally identified with *Helminthosporium lycopersici* Roldan.

5. The disease begins to appear in the field as early as June and July and is destructive to tomato during the wet months of the year. Fortunately tomatoes are not grown extensively during the wet season.

6. The conidia and mycelium of the fungus remained viable on infected tomato leaves which had been kept dry for six to eight months. The spores of the fungus may be disseminated by wind and by water splashed during rain. The germ tubes of germinating conidia enter the host through the stomata and by direct penetration.

7. Tomato varieties Marglobe, Dwarf Giant, Matchless, True Giant Ponderosa, Sunny-brook Earlina, and a native variety are susceptible to the disease.

8. Removal of all infected parts of the plants and complete destruction of all sources of inoculum should be practiced in order to reduce the injury caused by the disease.

9. Should the disease become serious, pepper, eggplant, and other vegetables should be planted instead of tomato.

LITERATURE CITED

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COLLEGE AND ALUMNI NOTES

The graduation of the following students was approved at the meeting of the College faculty on June 14: (*a*) Bachelor of Science in Agriculture—Odd Janlekha, José O. Jaug, Isidoro R. Romero, Chalerm Saiyananda, Ignacio R. Ang; (*b*) Associate in Agriculture—Silverio Q. Talavera.

The Los Baños chapter of the Rizal Center Fraternity held a dance at the Molawin Hall on June 19, on the occasion of the observance of Rizal's birthday.

The season's local intramural basketball championship was opened on June 20. In one contest the Juniors defeated the Seniors; in another the Rural High School boys lost to the Foresters.

The enrollment in the College this year is 558, exceeding last year's by 38. The Rural High School has 158.

The following papers were presented and discussed at the regular meeting of the Los Baños Biological Club on June 27, 1940:

Dr. F. M. Fronda, Mr. L. P. Zialcita, Mr. A. Dalisay. The Fertility of the duck egg.

Dr. N. Galvez. A Study on the art of weathering of volcanic tuffs under Los Baños conditions.

The College was represented at the U. P. faculty conference at Baguio by the following: Dean L. B. Uichanco, Miss E. Fraser, Messrs. F. O. Santos, R. B. Espino, V. Villegas, L. G. Gonzalez, S. M. Cendaña, V. C. Calma, V. B. Aragon, T. F. Buenaventura, A. B. Rotor, M. Manresa Jr., and Abel Silva.

The following Freshmen who were graduated either as valedictorians or salutatorians from high school were exempted from the payments of entrance, registration, and laboratory fees in the College, for the first semester of the academic year, 1940-41: Leopoldo S. Castillo, Fidel L. Leynes, Gil P. Nones, Maximo R. Novero, Faustino T. Orillo, Teodulo O. Paliangayan, Sebastian L. Rivera, Sabina S. Tuberan.

THE EXPERIMENT STATION

LIST OF AVAILABLE CIRCULARS

Circular No. 2.—Bud Rot of Coconut (Revised, June, 1934) - - - *By G. O. Oefemia*

Circular No. 3.—Experimental Errors and Application of the Probable Error to and the Interpretation of Experimental Results - - - - - - - - - - - - *By Nemesio B. Mendiola* (Published as Chapter IV in *A Manual of Plant Breeding for the Tropics*, 1926, also sold by THE PHILIPPINE AGRICULTURIST at ₱3.25, paper bound, and ₱5.25, cloth bound, in the Philippines, and ₱3.50 and ₱5.50 elsewhere, postpaid.)

Circular No. 5.—Poultry Raising Made Easy (Revised) - - - - *By F. M. Fronda*

Circular No. 7.—How to Produce New Varieties of Gumamela (Hibiscus) - - - - - - - - - - - - *By Nemesio B. Mendiola*

Circular No. 8.—Horse Breeding in the Philippines - - - - - *By Valente Villegas*

Circular No. 9.—Fences for Farm Animals - *By B. M. Gonzalez and J. P. Esguerra*

Circular No. 10.—Practical Directions for Coffee Planting - - - *By Pedro A. David*

Circular No. 11.—The New College Copra Drier—Prepared in *Department of Agricultural Chemistry* with cooperation of *Department of Agronomy and Extension*. (Revised by *Moises M. Kalaw*).

Circular No. 14.—Beriberi: Its Causes and Prevention - - - - - *By F. O. Santos*

Circular No. 15.—Cattle Raising under Philippine Conditions - - *By Valente Villegas*

Circular No. 16.—A Simple Farm Record for the Farmer - - *By Francisco M. Sacay*

Circular No. 17.—College Trapnest - - - - - - - *By F. M. Fronda and P. S. Paje*

Circular No. 18.—Surveying for Area with a Surveyor's Staff - *By Alexander Gordon*

Circular No. 19.—A Pageant: Illustrating the History and Growth of the College of Agriculture - - - - - - - - - *By Anne F. Cole*

Circular No. 20.—Amount of Nutrients in Philippine Food Materials - - - - - - - - *By F. O. Santos and S. J. Ascalon*

Circular No. 21.—Cassava Growing and Cassava Starch Manufacture - - - - - - - - - - *By Nemesio B. Mendiola*

Circular No. 22.—Goat Raising - - - - - - - - - - - - - - *By Valente Villegas*

Circular No. 23.—Curing Pork and Making Sausage for Home Use - - - - - - - - - - - - - - *By Mariano Mondoñedo*

Circular No. 24.—Construction and Operation of Silos in the College of Agriculture - - - - - - - - - - - - *By José P. Esguerra*

Circular No. 26.—Training Cattle and Carabaos for Work - - - *By Valente Villegas*

Circular No. 27.—Bunchy-top of Abacá - - - - - - - - - - - - *By G. O. Oefemia*

Circular No. 28.—Cotton Culture - - - - - - - - - - - - *By Eulalio P. Baltazar*

Circular No. 29.—Collegiate Education in Agriculture - - - - *By L. B. Uichanco*

Circular No. 30.—What Should Filipino Ornamental Gardens and Ornamental Plants Be? - - - - - - - - - - *By N. B. Mendiola*

Circular No. 31.—How to Slaughter and Dress Farm Animals - - - - - - - *By Valente Villegas and M. Mondoñedo*

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